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A
COMPLETE TREATISE
ON
ELECTRICITY,
IN
THEORY AND PRACTICE;
WITH
ORIGINAL EXPERIMENTS.

By TIBERIUS CAVALLO, F.R.S.

THE SECOND EDITION,
With conſiderable ADDITIONS and ALTERATIONS.

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31 DEC 72

TO

WILLIAM WATSON,
M. D. F. R. S. M. Br. Cur.

THIS

TREATISE

OF

ELECTRICITY

IS,

WITH THE GREATEST RESPECT,

INSCRIBED

BY HIS

MOST OBEDIENT,

AND MOST HUMBLE SERVANT,

TIBERIUS CAVALLO.

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THE

PREFACE.

THE deſign of the following Treatiſe is, to preſent to the public a comprehenſive view of the preſent ſtate of Electricity, reduced into as ſmall a compaſs as the nature of the ſcience would admit. It is divided into four parts, in each of which are contained ſuch particulars, as had ~~leſs~~ connection with the reſt; and the diſtinct view of which, it was thought, might be a means of preventing a confuſion of ideas in the minds of thoſe readers, who before have not been much converſant with the ſubject.

The firſt part treats of the laws of Electricity only; *i. e.* of ſuch natural laws concerning Electricity, as by innumerable experiments, have been found uniformly true, and are independent on any hypotheſis. In this part, the Author has not deſcended to any particulars, which were not clearly aſcertained, or which were inconſiderable; but he has, at the ſame time, taken care not to omit any thing material, or which ſeemed to promiſe future diſcoveries.

The ſecond part is merely hypothetical; relating not to facts, but to opinions. The great improbability of moſt of theſe hypotheſes determined the Author to render this part of his work as ſhort as poſſible.

The third part contains the practical branch of Electricity. Here the Author has taken care to inſert a deſcription of all the new improvements in the apparatus; which ſerve to leſſen the expence of it, and at the ſame time, to facilitate the performance of the experiments. As to the experiments themſelves, he has chiefly inſiſted on a few principal ones, which ſeemed moſt neceſſary to illuſtrate and confirm the laws of Electricity; omitting a great number of others, which he has met with, as they appeared to be only variations of the former. He has however given an account of ſome others, which, though not abſolutely neceſſary, ſeemed very deſerving of notice.

The fourth and laſt part contains a brief account of the principal experiments, which have been made by the Author himſelf, in purſuance of what occurred to him in the courſe of his ſtudies in this branch of philoſophy. In this part he has omitted to mention, not only thoſe attempts, which did not produce any conſiderable effect, but alſo the innumerable conjectures he formed about them and others, not yet brought to the teſt of actual obſervation.

The Author takes this opportunity of acknowledging the obligations he is under to ſeveral of his ingenious friends, for various experiments,

riments, and remarks, communicated by them; and particularly to the late Mr. WILLIAM HENLY, who did as much as laid in his power to inform him of every particular, which he thought would enrich and embelliſh the work.

It was deemed unneceſſary to point out thoſe gentlemen, whoſe experiments and obſervations introduced in this work, were before well known to the world; for which reaſon the Author has confined himſelf to the mention of the names of thoſe perſons, whoſe experiments were new, or not commonly noticed by the writers on this ſubject.

This ſecond edition, beſides various additions diſperſed throughout the work, is enriched by an Appendix, containing various intereſting particulars relating to Electricity.

To render the Treatiſe more intelligible and uſeful, four copperplates are added to it; and a copious index of the particulars which are moſt deſerving of attention.

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INTRODUCTION.

ARTS and ſcience, like kingdoms and nations, have each in their turn ſome happy period of glory and ſplendor, in which they more than ever attract the human attention, and, by caſting a ſtronger light than at other times, become the favourite object and purſuit of the age; but theſe periods are ſoon over, and a few years of luſtre and fame are often overbalanced by centuries of oblivion. From undergoing this fate, ſome ſciences are, however, excepted, which, owing to the vaſt and neceſſary extent of their uſe, and to the fruitfulneſs of their productions, are ever flouriſhing; and although once unknown, yet when fame had proclaimed their birth, or publiſhed their advancement, they never afterwards declined. Of this kind is Electricity, one of the moſt pleaſing and ſurpriſing among all the branches of natural philoſophy that ever were cultivated by man. This ſcience, after it began to ſhew the extent and generality of its power; after it was known to be one of the greateſt agents of nature; remained always in vogue, was profitably cultivated, irremittedly advanced, and is now brought to a ſtate, in which, inſtead of becoming ſterile, it ſeems further to engage the general attention, and to promiſe to its followers more munificent rewards. Optics, indeed, ſhews many enchanting and uſeful properties, but concerning viſion only; Magnetiſm exhibits the force of attraction, repulſion, and polarity in that ſubſtance called a Magnet: but Electricity, containing, as it were, all within its power, alone exhibits the effects of many ſciences, combines together different powers, and, by ſtriking the ſenſes in a particular and ſurprizing manner, affords pleaſure, and is of uſe to the ignorant as well as the philoſopher, the rich as well as the poor. In Electricity, we are pleaſed with beholding its penetrating light, exhibited in numberleſs different forms; we admire its attraction and repulſion, acting upon every kind of body; we are ſurpriſed by the ſhock, terrified by the exploſion and force of its battery; but when we conſider and examine it as the cauſe of thunder, lightning, aurora borealis, and other appearances of nature, whoſe direful effects we can in part imitate, explain, and even avert, we are then involved in a maze, that leaves nothing to contemplate but the inexpreſſible and permanent idea of admiration and wonder.

The earlieſt account we have of any known electrical effect, is by the famous ancient naturaliſt THEOPHRASTUS, who flouriſhed about 300 years before the preſent era. He tells us that *amber* (whoſe Greek name is *ηλεκτρον*, and from whence the name *Electricity* is derived) as well as the *lyncurium**, has the property of attracting light bodies. This was all that was known of the ſubject, for about fifteen

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* It hath been in a manner proved, that the *lyncurium* of THEOPHRASTUS is the very ſame ſubſtance that now goes under the name of *Tourmalin*; of which we ſhall have occaſion to ſpeak in the courſe of this Treatiſe.

teen centuries after THEOPHRASTUS; in which long period we find no mention in hiſtory of any perſon having made any diſcoveries, nor even any experiments in this branch of philoſophy; the ſcience remaining quite in the dark till the time of WM. GILBERT, an Engliſh phyſician, whoſe work *de magnete*, which contains ſeveral electrical experiments, was publiſhed in the year 1600; and who, for his diſcoveries in this new and uncultivated field, may be juſtly deemed the father of the preſent Electricity. He obſerved, that the property of attracting light bodies, after rubbing, was not peculiar to amber, or the *lyncurium*; but that many other bodies poſſeſſed it as well as amber. He mentions a great number of thoſe, together with many particulars, which, conſidering the ſtate of the ſcience at that time, may be deemed truly great and intereſting.

After GILBERT, the ſcience advancing, although by ſmall degrees, paſſed, as it were, from infancy to puerility; many an excellent philoſopher undertaking to examine nature in this walk: ſuch was Sir

Francis Bacon, Mr. Boyle, Otto Guericke, Sir Isaac Newton, and moſt of all Mr. Hawkesbee, a perſon to whom we are much indebted for many important diſcoveries, and a real advancement of Electricity. Mr. Hawkesbee was the firſt who obſerved the great electric power of glaſs; a ſubſtance, that, ſince his time, has been generally uſed by all Electricians, in preference to any other electric. He firſt remarked various appearances of the electric light, and the noiſe accompanied with it, together with a variety of phenomena relating to electric attraction and repulſion.

After Mr. Hawkesbee, the ſcience of Electricity, however hitherto advanced, remained for about twenty years in a ſtate of quieſcence, the attention of philoſophers being at that time engaged in other philoſophical ſubjects, which, on account of the new diſcoveries of the incomparable Sir Isaac Newton, were then greatly in repute. Mr. Grey was the firſt, after this period of oblivion, to bring the ſcience again to light. He, by his great diſcoveries, re-introduced it to the acquaintance of philoſophers, and from him the true flouriſhing era of Electricity may be ſaid to take its date.

The number of Electricians that hath been daily multiplying ſince Mr. GREY, the diſcoveries made, and the uſe derived from thoſe, till the preſent time, are matters really worthy of attention, and deſerve to be admired by every lover of the ſciences, and well-wiſher to the human race.

Whoever would make himſelf acquainted with the particular tranſactions concerning thoſe advances, ſhould read the elaborate Hiſtory of Electricity compiled by the learned Dr. PRIESTLEY, a work that will inform him of whatever had been done relative to the ſubject till its publication. I, for my part, muſt forbear making any long hiſtorical detail; this treatiſe being intended to give an account of the preſent ſtate of Electricity, in a methodical manner, and not an hiſtory of the ſame. I ſhall in general only obſerve, that although the ſcience had, through the indefatigable attention of ſo many ingenious perſons, and by the diſcoveries that were daily produced, excited the curioſity of philoſophers, and engaged their attention; yet, as the cauſes of any thing, whether ſmall or great, known or unknown, are ſeldom much attended to, if their effects are not ſtriking and ſingular; ſo Electricity had, till the year 1746, been ſtudied by none but Philoſophers. Its attraction could in part be imitated by a loadſtone; its light by a phoſphorus; and, in ſhort, nothing contributed to make Electricity the ſubject of the public attention, and excite a general curioſity, until the capital diſcovery of the vaſt accumulation of its power, in what is commonly called the *Leyden phial*, which was accidentally made in the memorable year 1745 *. Then, and not till then, the ſtudy of Electricity became general, ſurpriſed every beholder, and invited to the houſes of Electricians a greater number of ſpectators, than were before aſſembled together to obſerve any philoſophical experiments whatſoever.

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* This great diſcovery was made by Mr. Von Kleist, Dean of the Cathedral in Comin. See the third edition of Dr. Priestley's Hiſt. of Elect. Per. VIII. Sect. 1.

Since the time of this diſcovery, the prodigious number of Electricians experiments, and new facts that have been daily produced from every corner of Europe, and other parts of the world, is almoſt incredible. Diſcoveries crouded upon diſcoveries; improvements upon improvements; and the ſcience ever ſince that time went on with ſo rapid a courſe, and is now ſpreading ſo amazingly faſt, that it ſeems as if the ſubject would be ſoon exhauſted, and Electricians arrive at an end of their reſearches: but, however, the *ne plus ultra* is, in all probability, as yet at a great diſtance, and the young Electrician has a vaſt field before him, highly deſerving his attention, and promiſing further diſcoveries, perhaps equally, or more important than thoſe already made.

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COMPLETE TREATISE, &c.

PART I.

FUNDAMENTAL LAWS OF ELECTRICITY.

CHAP. I.

Containing the Explanation of ſome Terms principally uſed in Electricity.

IF a perſon, holding with one of his hands a clean and dry glaſs tube, rubs t with his other hand, alſo clean and dry, ſtroking it alternately upwards and downwards; and after a few ſtrokes, preſents to t ſmall light bits of paper, thread, meal, or any other ſubſtance, the rubbed ube will immediately attract them, and after a little time will repel them—preſently, attract them again; and ſo alternately continue this attraction, and repulſion, for a conſiderable time. If this tube be rubbed in the dark, and, after having been rubbed, a finger be preſentd to it at the diſtance of about half an inch, a lucid ſpark will be ſeen between the finger and the tube, accompanied with a ſnapping noiſe; the finger at the ſame time receiving a puſh, as if it was from air iſſuing with violence out of a ſmall pipe.

In this experiment, the attraction, repulſion, ſparkling, &c. are the effects of that unknown cauſe called *Electricity*; and hence they are called *electrical appearances.* The glaſs tube itſelf is called the *electric*, and all thoſe bodies which are capable by any means to produce ſuch effects, are called *electrics*; and as the rubbing awakes, as it were, in them the power of producing electrical appearances, they are therefore ſaid to be *excited* by the rubbing. The hand, or any other body that rubs an electric, is called the *rubber*; and if, inſtead of the perſon rubbing the glaſs tube, a machine a machine be conſtructed capable by any means to excite an electric, this will be an *electrical machine.*

If at the end of the tube oppoſite to that held by the hand, a wire of any length be tied, ſuſpending a metallic ball at its end, and the tube be excited as before, the metallic ball will, in this caſe, acquire all the properties of the excited tube, *i. e.* it will attract, ſparkle, &c. like the tube itſelf, the electric virtue paſſing through the wire to the ball: hence, the wire is ſaid to be a *conductor* of electricity; and all ſuch bodies as are capable to tranſmit the electric virtue, like the above-mentioned wire, are called *conductors.*

But if, inſtead of the wire, a ſilk ſtring be uſed in the above experiment, and the tube be excited as before, the ball in this caſe will not ſhew any ſigns of Electricity; the ſilk ſtring not permitting the electric virtue to paſs from the tube to the ball: hence the ſilk ſtring in this caſe, and all thoſe ſubſtances through which the electric virtue cannot be tranſmitted, are called *non-conductors.*

A body reſting intirely upon non-conductors is ſaid to be *inſulated*; ſo, in the laſt experiment, the metallic ball was inſulated; ſince it was ſuſpended intirely by the ſilk ſtring, which is a non-conductor. The bodies which are conductors, and thoſe which are non-conductors of electricity, together with their peculiar properties, as far as they are known, will be plainly laid down in the following chapters.

CHAP. II.

THE firſt and principal maxim in Electricity is, that all the known bodies in nature are divided into two claſſes, viz. Electrics, and Conductors; experiments ſhewing, that whatever ſubſtance is a Conductor of Electricity, cannot be excited, (hence Conductors are alſo called *non-electrics*); and that whatever ſubſtance can be excited, is not a Conductor, (hence *Electrics* and *Non-conductors* become ſynonymous terms *.) This maxim, however, is not to be conſidered as ſtrictly true and general; for in reality we know of no ſubſtance that may be called a perfect Electric, nor of any, that may be called a perfect Conductor; the Electric virtue finding ſome reſiſtance in going through the beſt Conductors, and being in part tranſmitted through, or over the ſurface of moſt, and perhaps all the Electrics. The leſs perfect Conductor any ſubſtance is, the nearer it comes to the nature of an Electric; and, on the other hand, the leſs perfect Electrics come neareſt to the nature of Conductors. The limits of thoſe two claſſes come ſo far one within the other, that there are many ſubſtances which may be actually excited, and at the ſame time are pretty good Conductors. If the reader deſires to know thoſe ambiguous ſubſtances, he muſt ſeek for the worſt Electrics among the Electrics, and for the worſt Conductors among the Conductors, excepting ſuch on which the experiment cannot be tried, as fluids, powders, &c.

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* Electrics are often alſo called *Electrics per ſe.*

The two following liſts contain, in general, all the Electrics and Conductors, diſpoſed in the order of their perfection, beginning in each liſt with the moſt perfect of their claſs. In this order, however, the reader muſt not expect a great exactneſs; that being impracticable, when ſubſtances are ſet under general articles; and at the ſame time is of little, if indeed of any uſe whatever.

ELECTRICS.

Glaſs, and all vitrifications, even thoſe of metals.

All precious ſtones, of which the moſt tranſparent are generally the beſt.

All reſins †, and reſinous compounds.

Amber.

Sulphur.

Baked wood.

All bituminous ſubſtances.

Wax.

Silk.

Cotton.

All dry animal ſubſtances, as feathers, wool, hair, &c.

Paper.

White ſugar, and ſugar-candy.

Air.

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† Under the name of reſins, I would be underſtood to mean all ſuch conſiſtent, oily, vegetable, productions as are inflammable, and not ſoluble in water; gum-lac, therefore, and all ſuch ſubſtances, improperly called gums, are alſo meant under this article. See MACQUER's Chemiſtry, vol. i. chap. 11.

Oils [‡].

Calces of metals and ſemi-metals.

The aſhes of animal and vegetable ſubſtances.

All dry vegetable ſubſtances.

All hard ſtones, of which the hardeſt are the beſt.

Many of the above-mentioned ſubſtances, and perhaps all thoſe upon which the experiment can be made, when very hot, loſe their electric property, and become quite, though not equally good, Conductors; ſo red-hot glaſs, melted reſin, hot air, baked wood made very hot, &c. become Conductors of electricity. But it is very remarkable, that the focus of a burning-glaſs is not a Conductor of electricity. It has been obſerved, that glaſs, eſpecially the hardeſt and beſt vitrified, is often a very bad Electric, ſometimes being quite a Conductor. The Abbé Nollet and others have made various experiments relative to this property of glaſs, but without determining intirely the cauſes which occaſion the difference. Glaſs veſſels, made for electrical purpoſes, are often rendered very good Electrics by uſe and time, though they might be very bad ones when new. On the other hand, ſome glaſs veſſels, which had been long uſed for excitation, have ſometimes loſt their power almoſt intirely. I have twice obſerved indiſputable caſes of this ſort.

[‡] Mr. CIGNA obſerved electrical attraction and repulſion between conducting ſubſtances plunged in oil. NOLLET's Letters, vol. iii, p. 168.

A glaſs veſſel, out of which the air has been exhauſted, on being rubbed, ſhews no ſigns of electricity upon its external ſurface, but all the electric power appears within the veſſel *; and a glaſs tube, or globe, with the air condenſed in it, or full of ſome conducting ſubſtance, is incapable of being excited. But a ſolid ſtick of glaſs, of ſealing-wax, &c. may be excited.

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* Although a glaſs veſſel, exhauſted of air, does not ſhew any ſigns of electricity without; yet it has been obſerved, that the electric power of a glaſs cylinder is the ſtrongeſt, when the air within it is a little rarefied, *viz.* ſomewhat leſs denſe than the external air. See l' Elettriciſmo Artificiale of G. B BECCARIA, § 411.

CONDUCTORS.

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Gold.
Silver.
Copper.
Braſs.
Iron.
Tin.
Quickſilver.
Lead.
Semi-metals.

Ores; of which the beſt are thoſe that contain the metallic part in the greateſt quantity, and come neareſt to a metalline ſtate.

Charcoals, made either of animal or of vegetable ſubſtances.

The fluids of an animal body.

All fluids, excepting air and oils *.

The effluvia of flaming bodies.

Ice †.

Snow.

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* Salt water is a better Conductor than freſh water.

† Mr. ACHARD, being at Berlin, in the month of January 1776, obſerved, that water froze to the twentieth degree below 0 of Reaumur's thermometer (which

Snow.

Moſt ſaline ſubſtances, of which the metallic ſalts are the beſt.

Stony ſubſtances, of which the hardeſt are the worſt.

Smoke.

The vapours of hot water.

Electricity pervades alſo vacuum, or the abſence of air cauſed by an air-pump, al-

(which anſwers to the thirteenth degree below 0 of Farenheit's ſcale) was an electric. He tried his experiments in the open air, where he found that a rod of ice two feet long, and two inches thick, was a very imperfect Conductor, when Reaumur's thermometer was at ſix degrees below 0, and that it would not in the leaſt conduct, when the thermometer was at 20°. By whirling a ſpheroid of ice in a proper machine, he even electrified the prime conductor, ſo as to attract, repel, give ſparks, &c. The ice that this gentleman made uſe of, was free from bubbles of air, and quite tranſparent; to produce which, he uſed to ſet a veſſel, containing diſtilled water, to be frozen, upon the window of a room, which was rather warm with reſpect to the ambient air; where the water began to freeze on one ſide of the veſſel, while on the other ſide it was ſtill liquid; in which caſe, he ſays that the bubbles of air, ſeparated from the part of the water that began to freeze firſt, and paſſed gradually into the liquid part, ſo as to leave a conſiderable thickneſs of ice quite tranſparent.

moſt as freely as the ſubſtance of a good Conductor *.

Beſides theſe, all bodies, in which more or leſs of ſome of the above-mentioned Conductors are contained, are alſo proportionably Conductors; thus, green vegetables, raw meat, &c. are Conductors, on account of the fluids they contain.

From this principle it follows, that all Electrics, before excitation, ſhould be well cleaned, dried, and ſome made even very hot, in order to free them from every humidity; otherwiſe they are ſo far from the nature of Electrics, that they become actually Conductors, on account of the moiſture

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* "I beg leave to mention in this place, as favourable to this hypotheſis, a moſt curious diſcovery made very lately by Mr. WALSH; who, being aſſiſted by Mr. de LUC to make a more perfect vacuum in the double or arched barometer, by boiling the quickſilver in the tube, found that the electric ſpark or ſhock would no more paſs through it, than through a ſtick of ſolid glaſs."—Dr. PRIESTLEY's Exp. and Obſ. on different Kinds of Air, vol. i. p. 284.

moiſture which they contain within their pores, or upon their ſurfaces.

In regard to the conducting power of charcoal, it muſt be obſerved, that all charcoal will not conduct equally well, there being ſome that will hardly conduct at all; and ſometimes is in ſuch a ſtate, that it will aſſiſt the paſſage of a large quantity of electric fluid along its ſurface, when it will not conduct it any other way. This difference, however, is not occaſioned by the difference of the wood from which the coals are made, but by the degree of heat that is applied in the proceſs of making them; the beſt Conductors being ſuch as have been expoſed to the greateſt heat *.

Whether the piece of wood in the proceſs of coaling is ſuffered to flame, or not, is quite immaterial; and the continuance of the ſame degree of heat has no apparent effect with reſpect to the conducting power of the charcoal.

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* See Dr. PRIESTLEY's ſecond volume of Obſervations on different Kinds of Air, Sec. xiv.

It will not be improper to obſerve in this place, the different changes from Conductor to Non-conductor, occaſioned in the ſame ſubſtance by different preparations. A piece of wood juſt cut from a tree is a good Conductor; let it be baked, and it becomes an Electric; burn it to a coal, and it is a good Conductor again; laſtly, let this coal be reduced to aſhes, and theſe will be impervious to electricity. Such changes are alſo obſervable in many other bodies; and very likely in all ſubſtances there is a gradation from the beſt Conductors to the beſt Non-conductors of Electricity.

CHAP. III.

Of the two Electricities.

IF, in the experiment mentioned in the firſt chapter, the perſon that rubs the tube be inſulated, *i. e.* be ſet with his feet upon a cake of reſin, a ſtool with glaſs feet, or any other good Electric, ſo that the communication between his body and the earth be cut off by means of Electrics; and if in this ſituation he rubs the tube with his hand, as before; this perſon, as well as the tube, will, in this caſe, appear electrified. If any light bodies be preſented to any part of his body, they will be attracted and repelled. If another perſon preſents his finger to him, a lucid ſpark will follow, with a ſnapping noiſe; and, in ſhort, this inſulated perſon will ſhew every ſign of electricity that the tube exhibits. But their electricities are not the ſame; the electricity of the tube being juſt the reverſe of the electricity of the perſon: and their particular appearances are the following:

1. Whenever a light body inſulated, as, for inſtance, a ſmall piece of cork ſuſpended by a ſilk thread, has been attracted by the tube, and afterwards repelled, if no conducting ſubſtance touches it in this ſtate of repulſion, it will not be attracted by the tube again. The ſame happens with the inſulated perſon; for when this light body has been once attracted by any part of his body, and afterwards repelled, it will not be attracted again; but if in this ſtate of repulſion the tube be preſented to it, then it will be attracted, and that violently, by the tube; and when repelled by the tube, it will be attracted by the inſulated perſon. Further, if two or more light inſulated bodies, like the abovementioned piece of cork, be ſeverally attracted by the tube, and when afterwards repelled, be brought within a ſmall diſtance of one another, they will repel each other, and, if well inſulated, continue in this electrified and repulſive ſtate for a conſiderable time. The ſame will happen, if they are preſented to the perſon inſtead of the tube; they will alſo, after being once repelled by this, repel one another. But,

if one, or more of thoſe light inſulated bodies be attracted and repelled by the tube; and one or more others be attracted and repelled by the perſon, and afterwards both or all (*i. e.* ſuch as were preſented to the tube, and ſuch as were preſented to the inſulated perſon) be brought within a ſufficient diſtance of one another, they will then, inſtead of repelling, attract each other; and inſtead of continuing electrified, extinguiſh at once every ſign of electricity. Theſe two electricities, therefore, are (as was ſaid before) the one juſt the contrary of the other, the one attracting what the other repels; and, as if one was an affirmative, and the other a negative power, when equal quantities of each are ſummed together, they balance each other, and loſe every property.

2. Another characteriſtic of each of the two electricities, conſiſts in the appearance of their light. If a pointed body, as a needle, a wire, or the like, be preſented to the excited tube in the dark, a lucid globule, like a ſtar, will be ſeen upon the point; but if this pointed body be preſented to the inſulated perſon, then in the

place of the ſtar a lucid pencil appears, compoſed of rays, ſeemingly iſſuing from the point, and diverging towards the perſon †.

3. Laſtly, in ſome experiments (which will be hereafter particularly mentioned, and this property better explained) the electricity of the tube, when in the act of paſſing from a body overcharged with it to another, either not electrified, or poſſeſſed of the contrary electricity, ſhews an indiſputable current from the former to the latter; and the electricity of the inſulated perſon, when in the act of paſſing from a body overcharged with it to another, either not electrified, or poſſeſſed of the contrary electricity, ſhews clearly a current from the latter to the former.

Theſe two electricities are not only obſerved in the above-mentioned experiment, but in ſeveral other caſes alſo; and they always accompany each other; for when different Electrics are rubbed, ſome will acquire one electricity, and others will acquire the contrary; the rubber, if inſulated, ſhewing at the ſame time, ſigns of the electricity contrary to that acquired by the excited electric: beſides this, almoſt all Electrics may be made to ſhew at pleaſure the one or the other electricity, according to the ſubſtance uſed for a rubber. Hence the following corollaries may be deduced: *viz.* 1. Whenever two different ſubſtances (being both inſulated, or only that which is a Conductor) are rubbed together, except they are both good Conductors, they will be both electrified, and one acquire the electricity contrary to the electricity of the other. 2. Almoſt all the Electrics may be made to acquire, at pleaſure, the one or the other electricity, by uſing proper rubbers.

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† This pencil of rays will appear better, if a pointed needle be preſented to the inſulated perſon, at the diſtance of about one inch from ſome part of his body, while he is actually rubbing the tube in the dark.

The firſt of theſe two electricities, *i. e.* that poſſeſſed by the glaſs tube in the above experiment, as it was thought to be the conſtant production of rubbed glaſs, was called the *Vitreous Electricity*; and the other, as it was firſt obſerved to be produced by reſinous ſubſtances, was called the *Reſinous Electricity*. The Vitreous Electricity is alſo called *Poſitive* or *Plus Electricity*, for a reaſon that will be conſidered in the courſe of this Treatiſe; and the Reſinous is called alſo *Negative* or *Minus Electricity*. A body, therefore, poſſeſſed of the Vitreous, Poſitive, or Plus Electricity, is that which ſhews ſuch ſigns as the tube was ſaid to exhibit; and a body poſſeſſed of the Reſinous, Negative, or Minus Electricity, is that which ſhews ſuch ſigns as the inſulated perſon was ſaid to exhibit in the above-mentioned experiment.

In the following Table may be ſeen what Electricity will be excited in different bodies, when rubbed with different ſubſtances. Smooth glaſs, for inſtance, will be found by this Table to acquire a Poſitive Electricity, when rubbed with any ſubſtance hitherto tried, except the back of a cat, (by which I mean the ſkin of a cat while on the animal alive); rough glaſs, *viz.* glaſs the poliſh of which has been deſtroyed by emery or otherwiſe, will be found to acquire the Poſitive Electricity, when rubbed with dry oiled ſilk, ſulphur, &c. and the Negative, when rubbed with woollen cloth, the hand, &c. and ſo of the reſt.

The back of a cat	Poſitive	Every ſubſtance with which it has been hitherto tried.
Smooth glaſs	Poſitive	Every ſubſtance hitherto tried, except the back of a cat.
Rough glaſs	Poſitive	Dry oiled ſilk, ſulphur, metals.
	Negative	Woollen cloth, quills, wood, paper, ſealing-wax, white-wax, the human hand.
Tourmalin	Poſitive	Amber, air[*].
	Negative	Diamond, the human hand.
Hare's ſkin	Poſitive	Metals, ſilk, loadſtone, leather, hand, paper, baked wood.
	Negative	Other finer furs.
White ſilk	Poſitive	Black ſilk, metals, black cloth.
	Negative	Paper, hand, hairs, weaſel's ſkin.
Black ſilk	Poſitive	Sealing-wax.
	Negative	Hare's, weaſel's, and ferret's ſkin, loadſtone, braſs, ſilver, iron, hand.
Sealing-wax	Poſitive	Metals.
	Negative	Hare's, weaſel's, and ferret's ſkin, hand, leather, woollen cloth, paper.
Baked wood	Poſitive	Silk.
	Negative	Flannel.

[*] i. e. By blowing with a pair of bellows upon it. By this means many Electrics may be excited, and ſome better if the air blown is hot, although, in both caſes, very little Electricity can be obtained.

The preceding Table might have been much extended, had I choſen to bring into it all the minutiæ attending this matter as far as is known; but this I have thought unneceſſary and impracticable, becauſe experiments of this kind are of ſo nice a nature, that they require the moſt ſcrupulous attention in making them; and then their effects depend upon ſo ſmall and variable circumſtances, that often the very ſame Electric, rubbed with the ſame rubber, gives at one time ſigns of one Electricity, and at another time ſigns of the contrary. A very little alteration in the ſurface, a different degree of dryneſs, and even a different application of the ſame ſubſtances, often occaſions a difference in the Electricity. I ſhall only obſerve in general, that as far as may be deduced from the greateſt number of experiments, it appears, that when different ſubſtances are rubbed together, that whoſe Electric power is the ſtrongeſt, in general acquires the Poſitive, and the other the Negative Electricity; and when two bodies, differing in the ſmoothneſs or roughneſs of their ſurfaces, are rubbed together, the ſmootheſt acquires the Poſitive, and the roughеſt the Negative Electricity. Theſe two qualities are often to be conſidered both together; for, except the two bodies are of the ſame ſubſtance, as ſmooth and rough glaſs, white and black ſilk, &c. they generally differ in both, viz. they have not the ſame electric power, and at the ſame time their ſurfaces differ in ſmoothneſs. This rule, however, is not to be conſidered as a conſtant and general one; for, according to this principle, it ſhould ſeem, that a piece of ſealing-wax, when rubbed with the hand, or paper, would acquire the Poſitive Electricity; but this is contrary to experience.

In caſe that two electric ſubſtances, equal in every reſpect, are rubbed together, it is to be obſerved that the ſubſtance which ſuffers the greateſt friction acquires the Negative, and the other the Poſitive Electricity. Suppoſe, for inſtance, that a piece A of ſilk be drawn acroſs another piece of ſilk B, in every reſpect equal to the former, ſo that the ſurface of the whole piece A, *i. e.* of one ſide of it, be ſucceſſively drawn over one part of the piece B, then A will acquire the Poſitive, and B the Negative Electricity. The reaſon of this may probably be, becauſe the part of the piece B, over which the piece A has been drawn, has acquired a greater degree of heat; for it has been obſerved, that heat rather diſpoſes bodies to be electrified Negatively.

C H A P. IV.

Of the different Methods of exciting Electrics.

RUBBING, as we obſerved before, is the general mean by which all electric ſubſtances that are at all excitable, may be excited. Whether they be rubbed with Electrics of a different ſort, or Conductors, they always ſhew ſigns of Electricity, and in general ſtronger when rubbed with Conductors, and weaker when rubbed with Electrics. But beſides friction, there are other means by which ſome Electrics may be cauſed to ſhew electric appearances: theſe are, by melting, or pouring a melted Electric into another ſubſtance; and by heating or cooling. The particulars obſerved by uſing the firſt of theſe two methods are the following:

If ſulphur be melted in an earthen veſſel, and left to cool upon Conductors: if taken out of the veſſel, when cold, it will be found ſtrongly electrical; but not at all ſo, if it be left to cool upon Electrics.

If ſulphur be melted in glaſs veſſels, and afterwards left to cool, they will both acquire a ſtrong Electricity, the ſulphur Negative, and the glaſs Poſitive, whether they be left to cool upon Electrics or Conductors; however, they always acquire a ſtronger power in the former caſe than in the latter, and a ſtronger ſtill, if the glaſs veſſel is coated with metal. It is remarkable that the ſulphur acquires no electricity till it begins to cool; its power increaſes in proportion as it contracts, and is the ſtrongeſt when in the ſtate of greateſt contraction; but then the electricity of the glaſs veſſel is at the ſame time the weakeſt.

If melted ſulphur be poured into a veſſel of baked wood, it acquires a Negative, and the wood a Poſitive Electricity; but if it be poured into ſulphur, or rough glaſs, it acquires no ſenſible electricity.

Melted ſulphur poured into a metal cup, and there left to cool, ſhews no ſigns of Electricity whilſt in the cup; but if they are ſeparated, they will then appear ſtrongly electrified, the ſulphur Plus, and the cup Minus. If the ſulphur is again replaced in the cup, every ſign of Electricity will vaniſh; but if, whilſt they are ſeparate, the Electricity of either of them is taken off, they will both, on being replaced, appear poſſeſſed of that Electricity which has not been taken off.

Melted wax, poured into glaſs, or wood, acquires a Negative Electricity, and leaves the glaſs or wood Poſitive. But ſealing-wax poured into ſulphur, acquires a Poſitive Electricity, and leaves the ſulphur Negative.

Chocolate, freſh from the mill, as it cools in the tin pans in which it is received, becomes ſtrongly electrical: when turned out of the pans, it retains for ſome time this property, but ſoon loſes it by handling. Melting it again in an iron ladle, and pouring it into the tin pans as at firſt, will for once, or twice, renew the power; but, when the maſs becomes very dry, and powdery in the ladle, the Electricity is revived no more by ſimple melting; but if then a little olive oil be added, and mixed well with the chocolate in the ladle, on pouring it into the tin pan, as at firſt, it will be found to have completely recovered its electric power †.

Now that we are ſpeaking of melted Electrics, it will not be improper to obſerve, that it ſometimes happens, that ſome electric ſubſtances, by being melted and left to cool, acquire an electrical power, which they retain for a conſiderable time, often for months together, eſpecially if they are preſerved free from dampneſs and duſt. Such effects have ſometimes induced Electricians to think, that ſome bodies are poſſeſſed of a permanent or perpetual Electricity, which is as inherent in their ſubſtance as the magnetic power of a loadſtone: in truth, however, no ſuch ſubſtance has yet been found; and although roſin, ſulphur, amber, and ſome other Electrics, ſhew ſigns of Electricity for a conſiderable time after they have been rendered electrical, yet their power is continually diminiſhing till it quite vaniſhes. It is remarkable, however, that ſulphur, reſinous, and bituminous ſubſtances, retain in general the electric power much longer than glaſs, or any other Electrics; the reaſon may be, that they do not attract moiſture like glaſs and other ſubſtances.

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† The above remark on chocolate, together with the method of reſtoring its power by means of olive oil, is a recent diſcovery of the late Mr. W. HENLY, F.R.S.

If a ſtick of ſealing-wax be broken into two pieces, the extremities that were contiguous will be found electrified, one poſitively, and the other negatively.

The property of exhibiting electrical phœnomena, by means of heating and cooling, was firſt obſerved in a hard ſemi-pellucid foſſil, known under the name of Tourmalin ‡. This ſtone, which is generally of a deep red, or purple colour, and ſeldom exceeds the ſize of a ſmall walnut, is common in ſeveral parts of the Eaſt Indies, and eſpecially in the iſland of Ceylon. Its properties in regard to Electricity are the following:

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‡ This ſtone is called *aſchentrickker* by the Dutch, from its property of attracting the aſhes, when laid near the fire. Linnæus calls it *lapis electricus*. See his Flora Zeylonica.

1. The Tourmalin, while kept in the ſame degree of heat, ſhews no ſigns of Electricity, but it will become electrical by increaſing or diminiſhing its heat, and ſtronger in the latter than in the former circumſtance. An exceedingly ſmall variation of temperature is often ſufficient to render the Tourmalin ſenſibly electrical.

2. Its Electricity does not appear all over its ſurface, but only on two oppoſite ſides, which may be called its poles, and they always lay in one right line with the center of the ſtone, and in the direction of its ſtrata; in which direction the ſtone is abſolutely opaque: though on the other, ſemi-tranſparent.

3. Whilſt the Tourmalin is heating, one of its ſides (diſtinguiſhed by A) is electri-

fied plus, and the other ſide B minus. But when it is cooling, A is minus, and B is plus *.

4. If it be heated, and ſuffered to cool without either of its ſides being touched, then A will appear poſitive, and B negative, all the time of its heating or cooling.

5. If this ſtone be excited by friction, like any other Electric, then each of its ſides, or both at once, may be made Poſitive.

6. If the Tourmalin be heated or cooled upon ſome other inſulated body, that body will be found electrified as well as the ſtone, and poſſeſſed of the Electricity contrary to that, acquired by that ſide of the ſtone which was laid upon it.

7. The

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* From this law may be eaſily deduced, that if one ſide of the ſtone, in ſome circumſtance or other, is growing hot, while the other is cooling, then both ſides will appear poſſeſſed of the ſame electricity at the ſame time; and if only one ſide changes its degree of heat, while the other remains the ſame, then the former ſide only will appear electrified.

7. The Electricity of each ſide, or of both, may be reverſed by heating or cooling the Tourmalin in contact with various ſubſtances; ſo if it is cooled, or heated in contact with the palm of the hand, that ſide of it, which would have been poſitive if cooled in the open air, is now negative; and that, which would have been negative, is now poſitive.

8. If a Tourmalin be cut into ſeveral parts, each piece will have its poſitive and negative poles, correſponding to the poſitive and negative ſides of the ſtone from which it was cut.

9. Theſe properties of the Tourmalin are alſo obſervable in vacuo, but not ſo ſtrong as in the open air.

10. If this ſtone be covered all over with ſome electric ſubſtance, as ſealing-wax, oil, &c. it will in general ſhow the ſame appearances with this coating, as without it.

11. Mr. WILLIAM CANTON hath lately obſerved a very vivid light to appear upon

the Tourmalin, while heating in the dark: he can by this determine, which end of the ſtone will be poſitive, and which negative. Further, when the ſtone is ſtrongly excited, it emits very ſtrong flaſhes from the poſitive to the negative end, in the dark †.

12. In the laſt place, it is remarkable that the power of the Tourmalin is ſometimes injured by the action of a ſtrong fire, ſometimes improved, and ſometimes not at all affected by it. The laws, however, of theſe uncertain effects have not yet been aſcertained.

The moſt of the above properties, which were firſt obſerved, and thought peculiar to the Tourmalin, have been found to belong to ſeveral hard precious ſtones, they being alſo made electrical by heating and cooling, and have their poſitive and negative ſides laying in the direction of their ſtrata or cryſtals; and, in ſhort, as far as has been obſerved, they have been found to act exactly like Tourmalins.

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† The Braſilian emerald, Mr. Canton has obſerved to have alſo this property of emitting light, whilſt heating in the dark.

We ſhall laſtly obſerve, in this chapter of excitation, that whenever an Electric is rubbed with another inſulated ſubſtance, although it acquires an electric power, and ſhews electrical appearances, yet that power is very weak; and in order to obtain a conſiderable Electricity, it is neceſſary that the rubber ſhould have a regular communication with the earth, by means of good Conductors.

CHAP. V.

Of Communicated Electricity.

IN the preceding Chapters we have conſidered Electricity no further than in reſpect to its quality; we have remarked the differences between the Poſitive and the Negative, and have noted which bodies, and by what means, they could acquire this property.---But now a vaſt proſpect is opening to our view, full of extraordinary appearances; and we are to conſider in this Chapter, not the mere kind of Electricity, but its numerous effects. Under the title of Communicated Electricity, falls almoſt all that is known of the ſubject; the paſſage of this virtue from one body to another is what cauſes its light; by being communicated to other bodies, we ſee its attraction; by its quick tranſition it is that it melts metals, deſtroys animal and vegetable life; and, in ſhort, it is by this communication that the ſcience is at all known and cultivated. In order, therefore, to preſerve perſpicuity, and diſtinction in deſcribing ſuch a multitude of facts, I ſhall employ more chapters on this ſubject, and arrange in each ſuch particulars as ſeem moſt proper to be placed together, at the ſame time contriving to reduce the whole into as few principal heads as is poſſible, without confuſion.

Whenever Electricity is by any means ſuperinduced on a body, it is there confined only by Electrics, and remains with that body a longer or a ſhorter time, according as the Electrics that confine it are more or leſs perfect. A glaſs tube, for inſtance, when rubbed, acquires a quantity of that power, whatever it is, which we call Electricity. That Electricity remains, and is perceivable upon the glaſs, inſomuch as it is ſurrounded by the air, which is an Electric; and as the air is in a more or leſs perfect electric ſtate, ſo that virtue is retained upon the glaſs longer or ſhorter *; and becauſe the air is never a perfect Electric, therefore the excited tube can never preſerve the acquired Electricity perpetually, but is continually imparting ſome of it to the contiguous air, or the conducting particles that float in that element, 'till at laſt it quite loſes its power. If a finger, or any other Conductor, be preſented towards an excited Electric, it will receive a ſpark, and in that ſpark part only of the Electricity of the Electric; but why not all? Becauſe the excited Electric, being a Non-conductor, cannot convey the Electricity of all its ſurface

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[*] An excited glaſs tube, if kept in a dry and rather warm place, for inſtance, at ſome diſtance from a good fire, will continue electrified above twenty hours.

to that ſide, to which the Conductor has been preſented. Hence, if a conducting ſubſtance be ſucceſſively preſented to different parts of an excited Electric, it will receive at every approach a ſpark, without repeating the excitation, 'till all the power of that Electric is exhauſted, and then a new excitation is neceſſary in order to revive it.

Whenever a Conductor communicating with the earth is exhibited at a convenient diſtance to an excited Electric, it acquires on that exhibited ſide an Electricity contrary to that poſſeſſed by the Electric: this Electricity increaſes the nearer it is approached, and at laſt, as there is an eager attraction between Poſitive and Negative Electricity, the Conductor receives a ſpark from the Electric, and ſo the balance is reſtored. If this Conductor does not communicate with the earth, but is inſulated, and approached to the excited Electric as before, then not only that ſide of it which is towards the Electric, but the oppoſite alſo, will appear electrified; with this difference, however, that the ſide, which is expoſed to the influence of the Electric, has acquired an Electricity contrary to that of the excited Electric, and the oppoſite ſide an Electricity of the ſame kind with that of the Electric. Theſe two different Electricities of the Conductor increaſe as it comes nearer to the Electric, and at laſt, the former receiving a ſpark from the latter, becomes throughout poſſeſſed of the ſame Electricity with the Electric from which it has received the ſpark. All theſe effects will happen in the ſame manner, if between the excited Electric and the approached Conductor there is interpoſed ſome other electric ſubſtance beſides air; as for inſtance, a thin plate of glaſs, roſin, ſealing-wax, &c. but then a ſpark can never come from the excited Electric to the Conductor, except it forces, or burſts its way through the interpoſed Electric, as it always does through the air. This diſplacing of the air is what cauſes the noiſe that attends a ſpark, and that noiſe is more or leſs loud in proportion to the quantity of Electricity, and to the reſiſtance it meets with in its paſſage.

An inſulated Conductor having received the Electricity from an excited Electric, (in which ſtate it is ſaid to be electrified by communication) will act in every reſpect like the excited Electric itſelf, except, that when it is touched by another Conductor communicating with the earth, the former gives one ſpark to the latter, and by that diſcharges all its Electricity. The reaſon why an electrified Conductor loſeth its Electricity all at once, when touched with another Conductor communicating with the earth, and not part of it only, like the excited Electric, is, becauſe the Electricity belonging to the whole of the Conductor is eaſily conducted through its own ſubſtance, to that ſide, to which the other Conductor is preſented. Hence it appears that, in general, the Electricity diſcharged from an electrified Conductor is much more powerful, than when diſcharged from an Electric; for the Conductor may acquire a great quantity of Electricity from an Electric, by receiving ſpark after ſpark, and afterwards if touched, will diſcharge it all at once, and not by little and little as it was received.

If an inſulated Conductor be touched with another Conductor electrified, it will acquire part of the Electricity belonging to the electrified Conductor, and afterwards each will ſhow ſigns of it. The Electricity in this caſe will not always be equally divided between the two Conductors, nor will it keep any proportion to the quantity of matter in each contained; but will obſerve the following laws.

1. If two inſulated Conductors, that in reſpect to their external ſurfaces are equal and ſimilar, and both, or only one electrified, are touched together, the Electricity will be equally divided among them.

2. If their ſurfaces are equal and diſſimilar, as for inſtance a ſquare foot of tin foil in one piece, and another ſquare foot of it cut in a long ſlip, then that body, whoſe ſurface has a greater extenſion, will acquire more Electricity than the other.

3. Laſtly, if their ſurfaces are unequal and diſſimilar, the Electricity that each acquires after the contact, ſeems pretty clear from experiments, and in conſequence of

the above two laws, to be in a compound proportion of their ſurfaces, and the extenſions of the ſame.

The electric ſpark (*i. e.* a ſeparate quantity of Electricity) will go a greater or leſs diſtance through the air, in order to reach a Conductor, according as its quantity is greater or leſs; as the parts from which it flies off, and on which it ſtrikes, are more ſharp or more blunt, and as the Conductor is more or leſs perfect. The noiſe together, and the light with which the ſpark is attended, is greater or leſs, according as the Electricity is greater or leſs; as the parts from which it flies, and on which it ſtrikes, are more blunt or more ſharp; and as the Conductor is more or leſs perfect. Thus, for inſtance, a ſharp-pointed body will throw off Electricity to, and receive it from a greater diſtance, than a body of any other ſhape; but then that paſſage occaſions no noiſe, and but little light; for, in this caſe, the Electricity does not come in a ſeparate large body, but by little and little, or rather by a continued ſtream. If a pointed wire is concealed in a glaſs tube, which projects a ſhort way beyond it, or if it is covered with tallow, bees-wax, ſulphur, &c. then it will take a ſtrong ſpark from an electrified Conductor.

It is remarkable in the caſe of points throwing off, or receiving Electricity, that a current of air is ſenſible at an electrified point, which is always in the direction of the point, whether the Electricity is poſitive or negative.

The electric ſpark, taken upon any part of a living animal body, cauſeth a diſagreeable ſenſation, which is more or leſs troubleſome, as the ſpark is ſtronger or weaker, and the part, upon which it is taken, is more or leſs delicate; and alſo according to the particular conſtitution of individuals.

A pretty large quantity of Electricity pervades the ſubſtance of a Conductor of a conſiderable length, with a ſurpriſing and imperceptible velocity; but a ſmall quantity of it has been found to take ſome little time in paſſing through a long, and leſs perfect Conductor.

Bodies, poſſeſſed of the ſame Electricity, whether poſitive or negative, repel each other. But bodies, poſſeſſed of different Electricities, attract each other; and there is no electric repulſion, but between bodies poſſeſſed of the ſame Electricity, nor electric attraction, but between bodies poſſeſſed of different Electricities, *i. e.* between bodies poſitively, and bodies negatively, electrified‡.

Electricity, ſtrongly communicated to inſulated animal bodies, quickens their pulſe, and promotes their perſpiration. If it is communicated to inſulated fruits, fluids, and in general, to every kind of bodies that are actually in a ſtate of evaporation, it alſo increaſeth that evaporation, and that in a greater or leſs degree, as thoſe bodies are more or leſs ſubject to evaporate of themſelves, as the veſſels, that contain the ſame, are Conductors or Electrics, and as they have a greater or leſs ſurface expoſed to the open air §.

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‡ This law, *i. e.* that there is no electric attraction, except between bodies poſſeſſed of different Electricities, will, perhaps, appear paradoxical, upon obſerving, that an excited Electric attracts ſmall bodies, which never were by any means made electrical before; but the paradox will ſoon vaniſh, if what has been ſaid above be conſidered, *i. e.* that when Conductors, and indeed Electrics too, come near an electrified body, they become actually poſſeſſed of a different Electricity, But this will appear much clearer from the experiments that are to be mentioned hereafter.

By encreaſing the perſpiration of vegetables, Electricity promotes their growth; it having been found, after ſeveral accurate experiments, that ſuch plants, which have been often, and long electrified, have ſhewed a more lively and forward appearance, than others of the ſame kind that were not electrified *.

When Electricity is communicated to inſulated veſſels, containing water, that is actually running from a pipe, the effects will, as far as may in groſs be deduced from experiments, obſerve the following laws.

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§ Although it has been by ſome pretended, that Electricity cauſed ſeveral ſubſtances to evaporate through the pores of glaſs, and metals, yet that could never be obſerved, though many accurate experiments were made for that purpoſe; beſides, this pretended evaporation, ſeems on all accounts exceedingly improbable.

* It is ſaid by Mr. KOESTLIN to have been found, that negative electrization retards both animal and vegetable life.—See his Latin Diſſertation on the effects of Electricity upon ſome organic bodies.

" 1. The electrified ſtream, though it divides, and carries the liquid further, is " neither ſenſibly accelerated nor retarded, " when the pipe through which it iſſues is " not leſs than a line in diameter.

" 2. Under this diameter, if the tube is " wide enough to let the liquid run in a " continued ſtream, Electricity accelerates " it a little, but leſs than a perſon would " imagine, if he judged by the numbers of " jets which are formed, and by the diſtance to which they go.

" 3. If the tube be a capillary one, from " which the water only drops naturally, " the electrified jet not only becomes a " continued ſtream, and even divided into " ſeveral ſtreams, but is alſo conſiderably " accelerated; and the ſmaller the capillary tube is, the greater, in proportion, " is the acceleration.

" 4. So great is the effect of the electric
" virtue, that it drives the water in a con-
" ſtant ſtream out of a very ſmall capillary
" tube, out of which it had not before been
" able even to drop."

The electric power has been found not to be affected by, or affect, the magnetic virtue of a loadſtone; neither is it affected by heat or cold; ſince, an iron bar made red-hot, or any conducting ſubſtance hard frozen, when electrified, attracts, repels, gives ſparks, &c. nearly in the ſame manner as in its natural temperature. Electric attraction is obſervable alſo in vacuo, where it acts nearly at the ſame diſtance as in the open air; and electric ſubſtances may alſo be excited in vacuo.

Laſtly, we ſhall conclude this chapter with remarking, that if the face or any part of the body, is preſented to an excited Electric, or to a Conductor ſtrongly electrified, it will feel as if a wind was blowing, or rather, as if as ſpider's web was drawn over it: alſo, if the noſtrils are preſented to an excited Electric, they will be affected by a ſmell, much reſembling that of phoſphorus; but communicated Electricity does not occaſion any ſuch ſenſation, except when a large quantity of it does ſuddenly paſs from one body to another. If bodies are kept for ſome time within the electric effluvia when ſtrong, they will retain the ſmell that they acquire, for a conſiderable time after.

CHAP. VI.

Of Electricity communicated to Electrics.

AS the Electric Virtue can be ſuperinduced on Conductors by communication, ſo may it alſo be communicated to Electrics: the difference however is, as might be expected, very remarkable; for when one ſide of a Conductor is preſented to an electrified body, the Electricity will inſtantly pervade its whole ſubſtance, on account of its conducting nature; whereas, when an Electric is preſented to another Electric excited, or to an electrified Conductor, it will with ſome difficulty acquire any Electricity, becauſe its ſubſtance is impervious to that virtue; and in order to make it acquire ſome, it muſt be ſeveral times, and in different parts, touched with the electrified body. That it is as difficult to deprive an Electric of its acquired Electricity, as it is to ſuperinduce it on its ſurface, I think might eaſily be ſuppoſed; for the very ſame quality, which cauſeth it to acquire that power ſlowly (namely its being a Non-conductor) makes it alſo part with it ſlowly; and, in order abſolutely to deprive the Electric of its acquired Electricity, it muſt be touched ſeveral times, and in almoſt every part of its ſurface, with ſome conducting ſubſtance.

In the preceding chapter we obſerved, that when an inſulated Conductor is preſented to an electrified body, it acquires, on the part neareſt to that body, a contrary Electricity; and on the oppoſite part, an Electricity of the ſame kind with that of the electrified body; we alſo obſerved, that theſe two Electricities increaſe, as the Conductor comes near to the electrified body, and that when the Conductor is arrived within the ſtriking diſtance of that body, a quantity of Electricity flies off from the latter; forces its way through the intermediate air, and, ſtriking upon the former, renders it throughout poſſeſſed of the ſame Electricity. Theſe effects are in a certain degree alſo obſervable when an Electric, inſtead of a Conductor, is preſented to an electrified body; for the Electric will alſo acquire, on different ſides, contrary Electricities: theſe Electricities increaſe, as the diſtance decreaſes; but, if at laſt a ſmall quantity of Electricity is communicated to one part of the Electric, that Electric will not become throughout poſſeſſed of one Electricity, but will ſtill, in ſome caſes, ſhew different Electricities on different ſides; and in ſome circumſtances, many repeated changes from poſitive to negative Electricity may be obſerved upon the ſame Electric, as will appear from the following experiment.

If the end of a pretty long glaſs tube be preſented to a body electrified, for inſtance poſitively, the tube will be found electrified poſitively alſo for the ſpace of one or two inches at the end; but, beyond that ſpace, will be found two or three inches electrified negatively; after that, another poſitive Electricity will appear, and ſo alternately, a poſitive and a negative zone will follow one another, always weaker and weaker in power, till at laſt they quite vaniſh *. Now the cauſe of theſe effects is always to be deduced from the two above-mentioned principles, *i. e.* the non-conducting quality of an Electric, and the properties of bodies in general to acquire an Electricity contrary to that poſſeſſed by another contiguous electrified body: ſo in the above experiment, that end of the tube which was preſented to the body electrified poſitively, before it received any Electricity from that body, appeared negative on the part preſented to it, but after it had received ſome Electricity, appeared to be poſitive no further than that Electricity could be ſpread over its ſurface; but beyond that place a part of the tube appeared to be negative, on account of its contiguity to the part electrified poſitively; after that, another place appeared to be poſitive, becauſe of its contiguity to the part electrified negatively, and ſo of the ſubſequent changes; and the poſitive Electricity of one part of the tube cannot mix with the adjoining negative part, ſo as to prevent theſe appearances, becauſe the non-conducting quality of the glaſs will always hinder ſuch an effect from takin place.

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* See PRIESTLEY's Hiſt. of Elect. Per. X. Sect. v. or Æpini Tentamen, p. 192.

If to one ſide of an Electric ſufficientl thin, as for inſtance a pane of commo window-glaſs, a plate of ſealing-wax, &c. be communicated one Electricity, and to the oppoſite ſide be communicated the contrary, that plate in that caſe is ſaid to be *charged*, and the two Electricities can never come together, except a communication of conducting ſubſtances be made between both ſides, or the Electric be broke by the power of electric attraction. Whe the two Electricities of a charged Electri are by any means united, and therefor their power deſtroyed, that Electric is the ſaid to be *diſcharged*, and the act of unio of theſe two oppoſite powers is, for a reaſon hereafter to be mentioned, called the *electric Shock*.

In order to avoid the difficulty of communicating Electricity to an electric plate, it is cuſtomary to coat the ſides of it with ſome conducting ſubſtance, as tin-foil, gilt paper, &c. by which means the charging and diſcharging becomes very eaſy; for when the Electricity is communicated to one part of the coating, it is immediately ſpread through all the parts of the Electric that are in contact with that coating, and when the Electric is to be diſcharged, it is ſufficient to make a conducting communication between the coatings of both ſides, in order to diſcharge entirely the Electricities of that Electric.

It will be readily underſtood why the coatings of both ſides of an Electric ſhould not come very near one another towards the edge of the plate, for then a communication between the ſame coatings is ready at hand, and although they do not abſolutely touch one another, yet when they are electrified, the Electricity will eaſily force a paſſage through the air, and, by paſſing over the ſurface of the Electric from one coating to the other, renders it incapable of receiving any charge *.

By means of charged Electrics, we may ſee a diſplay of the greateſt powers of Electricity; we can accumulate this power, and uſe it advantageouſly in different experiments. By conſidering the properties of a charged Electric, we become further and better acquainted with this ſcience, than by any other means; and for the enumeration of theſe properties the following chapter is employed.

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* The property of conducting the Electricity over the ſurface is ſo remarkable in ſome kinds of glaſs, that they are on this account abſolutely unfit for the purpoſe of charging and diſcharging.

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CHAP. VII.

Of charged Electrics, or the Leyden Phial.

IF a glaſs plate, whether ſmooth, or rough, is coated with ſome conducting ſubſtance on both ſides, ſo that the coatings do not come ſo very near the edge of the glaſs, as to render it unfit to be charged, and if to one of thoſe coatings be communicated ſome Electricity, the other coating, while communicating with the earth, or with a ſufficient quantity of conducting bodies, acquires by itſelf an equal quantity of the contrary Electricity; but if, whilſt one ſide is acquiring Electricity, the oppoſite ſide does not communicate with the earth, or with a ſufficient quantity of conducting ſubſtances, the glaſs cannot be charged [*]. Now the reaſon why, when one ſide of the glaſs is receiving one Electricity, the oppoſite ſide acquires the other, is the

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[*] Strictly ſpeaking, the glaſs in this caſe will be charged a little, becauſe the air which is contiguous to its coating is not a perfect Non-conductor.

ſame

ſame as obſerved in the preceding chapter, *i. e.* the property of bodies to acquire an Electricity contrary to that poſſeſſed by a contiguous electrified body; and the cauſe, that hinders theſe two Electricities from mixing together, is the interpoſition of the glaſs plate, which is impermeable to Electricity; but if the charge is too high, and the glaſs plate too thin, then the great attraction, between the two different Electrics, forces a paſſage through the glaſs, diſcharges it, and renders it unfit to receive another charge*.

Theſe effects happen in the ſame manner if the glaſs be not in the form of a plate, but in any other ſhape whatſoever, provided it is ſufficiently thin, it being not the form, but the thickneſs of the glaſs, that makes it more or leſs fit to be charged: and the thinner it is, the greater charge it is capable of receiving; for the ſtronger in proportion is the power of the Electricity of one ſide, to cauſe a contrary Electricity on the oppoſite ſide.

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* This remarkable property of Electricity was firſt ſatisfactorily obſerved (though not originally diſcovered, as we have already taken notice in the Introduction) at Leyden with a bottle containing ſome water, which ſerved for the inſide coating, and the undeſigned application of the hands on the outſide ſerved for another coating. A bottle coated on the inſide and outſide for the purpoſe of being charged, has from thence been called the *Leyden Phial*, otherwiſe an *electric Jar*; and the charging and diſcharging in general, of coated glaſs, has been called the *Leyden Experiment*.

How thick a glaſs plate or other Electric ſhould be, to become incapable of being charged, hath not yet been aſcertained.

A coated glaſs is capable of holding a greater charge in condenſed air, than when charged under the uſual preſſure of the atmoſphere.

If a coated glaſs plate, or phial, after being charged, be inſulated, and only one of its ſides be touched with ſome Conductor, that ſide will not part with its Electricity, becauſe the Electricity of one ſide exiſts in conſequence of the contrary Electricity on the oppoſite ſide, and both, by their mutual attraction, confine one another upon the ſurface of the glaſs. In order therefore to diſcharge that glaſs, both its coatings muſt be touched at the ſame time, and connected with the earth: or by means of ſome Conductor a communication muſt be made between them; and in this caſe the diſcharge is ſaid to be made through that Conductor.

When, in order to diſcharge a jar, one of its coatings is touched firſt with a Conductor, as for inſtance, with one end of a chain, nothing very particular in that caſe will appear *; but as ſoon as the other end of the chain comes within a ſufficient diſtance of the other coating, a ſpark will be ſeen between the end of the chain, and that coating, accompanied with a noiſe, &c. juſt as when an excited Electric, or an electrified Conductor, is made to communicate with another Conductor; but the power, the light, and the report is in general much

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* If one coating of a charged jar communicates with the earth while the other coating is expoſed to the free air for ſome time, the charge of that jar will be ſilently and gradually diſſipated; for while the Electricity of one ſide goes to the earth, the Electricity of the other is communicated to the air, which, as we obſerved before, is never an Electric.

greater than that of a ſpark taken from a body ſimply electrified.

If the communication between the two ſides of a charged jar be made by imperfect Conductors, as a ſlender piece of wood, a wet packthread, &c. the diſcharge will be made ſilently and without exploſion.

It is remarkable, that the ſpark occaſioned by the diſcharge of charged Electrics, although it is more denſe, more powerful, and makes a greater report, yet is not ſo long as the ſpark drawn from an electrified Conductor.

When the diſcharge of a jar is made through the body of a living animal, it occaſions a ſudden motion, by contracting the muſcles through which it paſſes, and gives a diſagreeable ſenſation; for which reaſon, the effect of diſcharging an electric jar has been generally called the *electric Shock*. This ſhock is more ſenſibly felt by ſome perſons than by others, and it is ſaid that ſome people are not at all affected by it.

The force of the electric ſhock, occaſioned by glaſſes of the ſame thickneſs, is greater or leſs in proportion to the quantity of coated ſurface, and the height of the charge. Upon this principle, the power of the ſaid ſhock, by increaſing the quantity of coated glaſs, may be augmented at pleaſure, provided means be uſed powerful enough to charge it.

A number of coated jars connected together in ſuch manner that their whole force may be united, and act like one jar, conſtitutes what is called an *electrical Battery.* This battery is the moſt formidable, and entertaining part of an electrical apparatus, and by its uſe many wonderful effects are produced:—but as the performing of theſe belongs rather to the practical, than to the preſent part of this Treatiſe, I ſhall only enumerate them in this place, and reſerve further particulars for the third part of this work.

In making the diſcharge of an electric jar, it is ſurprizing to obſerve with what quickneſs the Electriciy performs the circuit from one ſide of the glaſs to the other. It has been found to employ no perceivable time in going through a Conductor of ſeveral miles, which connected the two coatings of a phial *.

The force and noiſe of an electric ſhock is not affected by the inflexions of the Conductor, through which it goes, but it is ſenſibly weakened by its length; hence, when the circuit, *i. e.* the communication between the two ſides of the electric phial, is made by one perſon touching one ſide with one hand, and the oppoſite ſide with the other, the ſhock is ſtronger than when the circuit is formed by many perſons together joining hands.

That the Electricity finds ſome obſtruction in going through even the beſt Conductors, appears evident, from this, that in ſome caſes it will prefer a ſhort paſſage through the air, to a long one through Conductors, even the moſt perfect. This obſtruction is greater in thoſe places, where the Conductors, forming the circuit, do not lie in perfect contact; and if, the circuit being compoſed of Conductors of different natures, the Electricity be obliged to paſs from one Conductor to another leſs perfect, the obctruction is ſtill greater. If a ſmall interruption of the circuit be made in water, on making the diſcharge (notwithſtanding that the water is a Conductor) a ſpark will be ſeen in it, which never fails to agitate the water, and often breaks the veſſel that contains it.

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* PRIESTLEY's Hiſt. of Elect. Per. VIII. Sect. ii.

A ſtrong ſhock, ſent through an animal or a plant, puts an end to animal as well as to vegetable life. If the circuit be interrupted by one or more Electrics, or imperfect Conductors, of a moderate thickneſs, the electric ſhock will break them, and in ſome circumſtances diſperſe them in every direction, and in ſuch a manner as if the force proceeded from the center of every one of the interpoſed bodies *.

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* In ſeveral inſtances the effect of a ſhock upon an interpoſed body is evidently greater on that ſide of it which communicates with that coating of the jar or battery, that is poſſeſſed of the poſitive Electricity. But of this more will be ſaid hereafter.

A ſtrong ſhock, ſent through a ſlender piece of metal, makes it inſtantly red-hot, melts it, and, if the fuſion is perfect, reduces it into globules of different magnitudes. If the metal be incloſed between pieces of glaſs, the ſhock, by melting it, will force it into the ſubſtance of the glaſs, ſo that afterwards it cannot be taken off without ſcraping part of the glaſs with it. In this experiment the glaſſes are ſhattered to pieces, and it is ſeldom that they reſiſt the force of a ſtrong ſhock.

If the glaſſes, incloſing the metal, be preſſed by heavy weights, then a remarkable ſmall ſhock is capable often not only to raiſe the weight, but to break ſuch thick glaſſes, that otherwiſe require the force of a large battery. Thick pieces of glaſs may be alſo broken into innumerable fragments, by only ſending a ſhock over a ſmall part of their ſurface, which are preſſed by weights, without the interpoſition of any metal. When theſe pieces of glaſs are not broken, they are marked by the exploſion with the moſt lively priſmatic colours, which lie ſometimes confuſed, and ſometimes

times in their priſmatic order. The coloured ſpot is evidently formed by thin plates or ſcales, in part ſeparated from the ſurface of the glaſs; and it generally occupies the ſpace of about one inch in length, and half an inch in breadth.

In melting wires of the ſame metal by the electric ſhock, it muſt be obſerved, that the forces required for that purpoſe muſt be greater or leſs, according as the lengths or thickneſſes of the wires are greater or leſs: but they are far from bearing any direct proportion to the quantity of metal; for if a wire of a given length and diameter be barely melted by a large battery, a wire of equal length and twice the ſubſtance, would perhaps take ten ſuch batteries to produce the ſame effect upon it.

When a moderate ſhock * is ſent through an imperfect metal (eſpecially if the circuit is formed by ſeveral pieces, as by a chain), a black

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* By a moderate ſhock here, I mean, one that is not able to melt the metal through which it paſſes.

a black duſt, in the form of ſmoke, will be ſeen to proceed from the metal, which is thought to be ſome of the metal itſelf partly calcined, and, by the violence of the exploſion, forced from it.

If ſuch circuit, or part of it, be laid upon a piece of paper, glaſs, or other Non-conductor, this, after the exploſion, will be found ſtained with ſome indelible marks, and often ſhew evident ſigns of having been burnt. A long and permanent track may be marked upon glaſs, and ſome other bodies, by the electric exploſion, if the interruption of the circuit be made upon its ſurface.

What is more remarkable, in conſidering the effects of Electricity on metals, is, that it revivifies their calces; and, like a true phlogiſtic proceſs, when an exploſion is made between two pieces of the ſame, they, in part, return into their metalline form.

Although we obſerved, in the fifth chapter, that Electricity and Magnetiſm did not interfere with one another's action, yet that muſt not be underſtood in general, and when a large force of Electricity is meant; for this is capable not only of deſtroying the virtue, or of reverſing the poles of a magnetic needle, but even of giving it that virtue. When the charge of ten, eight, and even a leſs number of ſquare feet of coated glaſs is ſent through a fine ſewing-needle, it will often give it polarity, ſo that it will traverſe when laid on water *. It is remarkable, that if the needle be ſtruck, lying eaſt and weſt, that end of it which is entered by the ſhock, will afterwards point north; but if the needle be ſtruck, lying north and ſouth, that end of it which lay towards the north, will in any caſe point north; and the needle will acquire a ſtronger virtue in this, than in the former caſe. Laſtly, if the needle is ſet perpendicular to the horizon, and the elec-

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* A ſmart ſtroke of a hammer will make a needle magnetic: but they ſhould always be tried before the experiment: for many ſmall needles will traverſe upon water, without the electric ſhock, or the ſtroke of the hammer.

tric ſhock is given to either point of it, afterwards the lower extremity of the needle will point north*.

That the electric ſpark ſhould kindle inflammable ſubſtances, I think might be expected, when its power has been conſidered in many circumſtances, in which it has been obſerved to act as a moſt penetrating and extraordinary fire. In firing ſeveral ſubſtances a ſmall ſhock is ſufficient; and inflammable ſpirits may be fired even by a ſpark proceeding from an electrified Conductor.

If the moderate charge of a large battery is diſcharged between two ſmooth ſurfaces of metals, or ſemi-metals, lying at a ſmall diſtance from each other, a beautiful ſpot will be marked upon them. This conſiſts of one central ſpot, and ſome concentric circles †, which are more or leſs diſtinct,

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* See Dr. FRANKLIN's Letters, p. 90, and BECCARIA's Artificial Electricity, § 731, 732, 733, 734.

† The central ſpot as well as the circles lie at a little diſtance from one another; and they are compoſed of dots and cavities, indicating a true fuſion.

and

and more or leſs in number, according as the metal upon which they are marked, requires a leſs or greater degree of heat to be melted, and as a greater or leſs force is employed.

If the exploſion of a battery, iſſuing from a pointed body, as the point of a needle, be repeatedly taken upon the plain ſurface of a piece of metal ſituated at a little diſtance from the point, or if iſſuing from the ſurface, be taken upon the point, that metal will be marked with a coloured ſpot, conſiſting of all the priſmatic colours diſpoſed in circles, and evidently formed by ſcales, or thin plates of the metal ſeparated by the force of the exploſion *.

When the diſcharge of a battery is made by bringing the ends of two Conductors, communicating with the inſide, and the outſide of the battery, in contact with, or at a little diſtance from the ſurface of ſeveral conducting ſubſtances, as water, raw meat, &c.

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* For further particulars concerning thoſe circles, ſee the Phil. Tranſ. vol. LVIII.

it is obſervable that the Electricity, inſtead of entering thoſe ſubſtances, goes over their ſurface, and in a lucid ſeparate body reaches from Conductor to Conductor; ſometimes it prefers a much longer paſſage over the ſurface, to a ſhorter one through any ſubſtance. In this caſe the exploſion never fails to give a concuſſion to the body, over whoſe ſurface it paſſes.

The electric exploſion, or even electric ſparks, when taken in different kinds of air, or permanently elaſtic fluid, was obſerved by Dr. PRIESTLEY to act like a true phlogiſtic proceſs *. But upon a nicer examination, it ſeems that the phlogiſtic principle does not proceed from the electric fluid itſelf, but is detached, by the force of Electricity, from thoſe Conductors, between which the exploſions or ſparks are taken †. It may be alſo mentioned in this place to have been

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* See Dr. PRIESTLEY's ſecond vol. of Obſervations on different kinds of air.

† See my Treatiſe on Air, and other permanently elaſtic Fluids, p. 433.

found by Dr. PRIESTLEY, that every kind of permanently elaſtic fluid is a Non-conductor of Electricity; but probably they are not all of the ſame degree. The colour of the electric ſpark, although equally viſible, yet is not of the ſame colour in every ſort of elaſtic fluid. In inflammable and in alkaline air, it appears of a purple or red colour; in fixed air it appears white.

The electric exploſions taken upon the leaves of certain flowers, changes their colour *.

Beſides the above-mentioned properties of charged glaſs, there are a few more obſerved, which as yet have neither been ſufficiently inveſtigated, nor ſo far purſued as to be reduced under any general laws. They afford a great field for ſpeculation, and ſeem to be more intimately connected with the nature of Electrics in general; but it ſeems not proper to make any general concluſions from the facts already known, at leaſt ſo as to

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† Dr. PRIESTLEY's Hiſt. of Electricity, Per. VII.

to be inſerted in this part of the preſent treatiſe. I ſhall therefore employ a chapter for the narration of the ſame, in which I ſhall relate the principal, and more promiſing experiments hitherto made, and take notice of the beſt conjectures offered for their explanation. This chapter will be found at the end of the third part, in which place, I think, it will be more acceptable to my readers, particularly ſuch, who have not been much converſant with Electricity, and therefore require firſt the deſcription of the electrical apparatus, and the knowledge of the experiments neceſſary to prove the facts recited.

CHAP. VIII.

Of Atmoſpherical Electricity.

WHOEVER has remarked the numerous properties of Electricity already mentioned, and has conſidered their extenſive power, will, I doubt not, be greatly ſurpriſed, when he compares the ſtate, in which the ſcience remained half a century ago, with that in which it is at preſent; but his wonder will ſtill increaſe, when he is told that Electricity is not only to be obſerved by rubbing an Electric, or warming a Tourmalin, but that it has been found to exiſt in the air, rain, and clouds; that thunder and lightning have been diſcovered to be its effects; and that, in ſhort, whatever has the appearance of fire, or of any thing extraordinary in the atmoſphere, and upon the earth, has been attributed to Electricity.

That the effects of Electricity bore a great reſemblance to thunder and lightning, had been ſeveral times remarked by philoſophers, and eſpecially by the learned Abbé NOLLET; but that they ſhould actually be found to be effects of the ſame cauſe, and that the phenomena of Electricity ſhould be imitated by lightning, or thoſe of lightning by Electricity, was neither thought poſſible, nor ſuſpected, till the celebrated Dr. FRANKLIN made the bold aſſertion, and the French philoſophers firſt, and afterwards Dr. FRANKLIN proved the fact by undeniable arguments in the year 1752.

The ſimilarity of lightning and Electricity is not to be remarked in a few appearances only, but it is obſervable throughout all their numerous effects, and there is not a ſingle phenomenon of the one, but may be imitated by the other. Lightning deſtroys edifices, animals, trees, &c.; lightning goes through the beſt Conductors, which it meets in its way, and, if its paſſage is obſtructed by Electrics, or leſs perfect Conductors, it rends them, and diſperſes them in every direction; lightning burns, and melts metals and other ſubſtances; a ſtroke of lightning often diſturbs the virtue of a magnet, and gives polarity to ferruginous ſubſtances; and all theſe effects, as has been obſerved above, may be produced by Electricity. But, independent of the great ſimilarity exiſting between lightning and Electricity, what fully proves their identity is, that the matter of lightning may be actually brought down from the clouds by means of inſulated and pointed metallic rods, or by electrical kites, and with it any known electrical experiment may be performed.

Clouds, as well as rain, ſnow, and hail, that fall from them, are almoſt always electrified, but oftener negatively than poſitively; and the lightning, accompanied with the thunder, is the effect of the Electricity, which, darting from a cloud, or a number of clouds, highly electrified, ſtrikes into another cloud, or elſe upon the earth; in which caſe it prefers the moſt lofty and pointed places, and by this ſtroke produces all thoſe dreadful effects, that are known to be occaſioned by lightning.

The air, at ſome diſtance from houſes, trees, maſts of ſhips, &c. is generally electrified poſitively, particularly in froſty, clear, or foggy weather; but how the air, the fogs, and the clouds become electrified has not yet been aſcertained, although ſeveral conjectures have been offered.

After that Electricity, and the matter of lightning were found to be the ſame thing, philoſophers began to ſuſpect the action of Electricity to be where it had before been leſs imagined, and not without reaſon endeavoured to reconcile to it ſeveral other natural appearances. The aurora borealis, or northern light, was ſoon attributed to Electricity, on obſerving that by this that flaming light may be imitated *, and that the aurora borealis, when very ſtrong, has been known to diſturb the magnetic needle †, which is alſo an effect of Electricity.

The accentions, that are often ſeen in the atmoſphere (commonly called *falling Stars)* are thought to be electrical appearances. The ſame is alſo ſuppoſed to be the cauſe of ſuch other meteors like white clouds, that often appear by night-time, particularly in hot climates. Beſides thoſe phenomena, water-ſpouts, hurricanes, whirlwinds, and even earthquakes have been attributed to Electricity. But now, perhaps, the reader will think philoſophers too extravagant, in going ſo far with Electricity.

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* The late Mr. CANTON frequently collected Electricity in a conſiderable degree, during the time of an aurora borealis. His apparatus for that purpoſe conſiſted of an inſulated fiſhing rod, erected on the top of his houſe, and having a wire twiſted round.

† See the Phil. Tranſ. vol. LIX. page 88.

Such thoughts ſeem at firſt ſight to be extravagancies; but if it be conſidered, that they do not appear to contradict the known laws of nature, that they are not aſſertions abſolutely void of proofs, add that they are the thoughts of great philoſophers, then, I think, they may be admitted, at leaſt ſo far as to be tried on proper occaſions, and to be conſidered as the moſt plauſible conjectures yet offered in explanation of the moſt ſurprizing phenomena of nature*.

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* For further conjectures ſee Dr. FRANKLIN's Letters, and Dr. PRIESTLEY's Hiſt. of Elect.

CHAP.

CHAP. IX.

Advantages derived from Electricity.

NATURE, ever wiſe and admirable in her actions, ſeems to follow a certain ſimilarity in her works with a conformity of operations, and, from the ſimpleſt to the moſt complicated of her objects, an analogy is obſervable, which, as it is wonderful to be conſidered, ſo it is inſtructive and uſeful. It is on account of this analogy, that whenever a diſcovery is made in any part of natural philoſophy; whenever a ſcience is advanced, we not only attain to the knowledge of that ſingle law, or particular ſcience, but at the ſame time acquire means in general of inveſtigating the operations of nature with ſomewhat more certainty and accuracy, and by purſuing that analogy we are enabled to make further diſcoveries, and to improve every branch of knowledge. How far Electricity has contributed towards this purpoſe, I think is unneceſſary to be further proved, when its action has been ſhown to be ſo general, and ſo powerful, as to perform what no art can operate. But, beſides the field that Electricity has opened for further diſcoveries, and the ſatisfaction of that curioſity, which before attended the contemplation of ſo many wonderful phenomena as have been explained by this ſcience, there are two great advantages derived from Electricity; the one is a defence againſt the direful effects of lightning, and the other a remedy for many diſorders incident to the human body.

In order to guard edifices or ſhips from being damaged by lightning, it was judiciouſly propoſed, by Dr. FRANKLIN, to raiſe a metallic Conductor ſome feet above the higheſt part of the building, and continue it down the wall till it penetrated ſome feet into the ground; by this means the houſe could never receive any damage, for whenever the lightning ſhould happen to fall upon it, it is evident that the Conductor, being of metal, and higher than any part of the building, would certainly attract it, and, by conducting it to the ground, hinder that building from receiving any damage;

for it is known that Electricity always ſtrikes the neareſt and beſt Conductors, that it meets with in its way.

The reaſonableneſs and truth of this aſſertion has been confirmed by numberleſs facts, and the practice of raiſing ſuch Conductors has been found exceedingly uſeful, particularly in hot climates, where thunder-ſtorms are very frequent, and the damages occaſioned by the ſame, too often experienced.

In regard to the conſtruction of ſuch Conductors, there have been ſome controverſies among Electricians; and the moſt advantageous manner of uſing them has not, without a great many experiments, and but very lately, been aſcertained. Some philoſophers have aſſerted that ſuch Conductors ſhould terminate in a blunt end, that they might the leſs invite the lightning from the clouds; for a blunt end will not attract Electricity from ſo great a diſtance as a ſharp point. But ſome other philoſophers have thought a pointed termination to be much preferable to a blunt one, and their aſſertion ſeems, on the following accounts, founded on much better reaſoning.

A ſharp-pointed Conductor, it is true, will attract Electricity from a greater diſtance than a blunt one, but at the ſame time, will attract and conduct it by little and little, or rather by a continued ſtream, in which manner a remarkably ſmall Conductor is capable of conducting a very great quantity of Electricity; whereas a blunt-terminated Conductor attracts the Electricity in a full ſeparate body, or exploſion, in which manner it is often made red-hot, melted, and even exploded in ſmoke, and by ſuch a quantity of Electricity, as perhaps would not have at all affected it, if it had been ſharply pointed.

A ſharp-pointed Conductor, certainly, invites the matter of lightning eaſier than a blunt one, but to invite, receive, and conduct it in ſmall quantities never endangers the Conductor; and the object of fixing a Conductor to a houſe, is to protect the houſe from the effects of, and not the Conductor from tranſmitting the lightning.

It is an obſervation much in favour of ſharp-pointed Conductors, that ſuch ſteeples of churches, and edifices in general, as are terminated by pointed metallic ornaments, have very ſeldom been known to be ſtruck by lightning, whereas others that have flat or blunt terminations, and have a great quantity of metal in a manner inſulated on their tops, are often ſtruck by it, and it is but ſeldom that they eſcape without great damage.

Beſides thoſe conſiderations, a ſharp-pointed Conductor, by the ſame property of attracting Electricity more than a blunt one, may actually prevent a ſtroke of lightning *, to do which a blunt-ended one is abſolutely incapable.

A Conductor therefore to guard a building, as it is now commonly uſed in conſequence of ſeveral conſiderations, and experiments,

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* This and other properties of pointed Conductors will be made to appear very evidently by experiments.

periments, ſhould conſiſt of one iron rod * about three quarters of an inch thick, faſtened to the wall of the building, not by iron cramps, but by wooden ones. If this Conductor was quite detached from the building, and ſupported by wooden poſts at the diſtance of one or two feet from the wall, it would be much better for common edifices, but it is more particularly adviſable for powder-magazines, powder-mills, and all ſuch buildings as contain combuſtibles ready to take fire. The upper end of the Conductor ſhould be terminated in a pyramidal form, with the edges, as well as the point, very ſharp †; and if the Conductor is of iron, it ſhould be gilt, or painted for the length of one or two feet. This ſharp end ſhould be elevated above the higheſt part of the building (as above a ſtack of chimnies, to which it may be

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* Copper would do much better than iron for a Conductor; it being a more perfect Conductor of Electricity, and at the ſame time not being ſubject to contract ruſt as ſoon as iron.

† This pyramidal termination of the Conductor is an improvement of an ingenious Electrician, Mr. SWIFT at Greenwich.

faſtened) at leaſt five or ſix feet. The lower end of the Conductor ſhould be driven five or ſix feet into the ground, and in a direction leading from the foundations; or it would be better to connect it with the neareſt piece of water, if any be at hand. If this conductor, on account of the difficulty of adapting it to the form of the building, cannot conveniently be made of one rod, then care ſhould be taken, that where the pieces meet, they be made to come in as perfect contact with one another as poſſible; for, as we obſerved before, Electricity finds conſiderable obſtruction where the Conductor is interrupted.

For an edifice of a moderate ſize, one Conductor, in the manner already deſcribed, is perhaps ſufficient; but, in order to ſecure a large building from ſuſtaining any damage by lightning, there ſhould be two, three, or more Conductors, in proportion to the extent of the building.

On board ſhips a chain has often been uſed for this purpoſe, which, on account of its pliableneſs, has been found very con-

venient,

venient, and eaſy to be managed among the rigging of the veſſel; but as the Electricity finds a great obſtruction in going through the ſeveral links, for which reaſon chains have been actually broken by the lightning, ſo their uſe has now been almoſt intirely laid aſide, and in their ſtead, copper wires a little thicker than a gooſe-quill have been ſubſtituted, and found to anſwer very well. One of theſe wires ſhould be elevated two or three feet above the higheſt maſt in the veſſel; this ſhould be continued down the maſt, as far as the deck, where, by bending, it ſhould be adapted to the ſurface of ſuch parts, over which it may moſt conveniently be placed, and, by continuing it down the ſide of the veſſel, it ſhould be always made to communicate with the water of the ſea.

In regard to perſonal ſecurity, in caſe a thunder-ſtorm were to happen while a perſon is in a houſe not furniſhed with a proper Conductor, it is adviſeable not to ſtand near places where there is any metal, as chimnies, gilt frames, iron caſements, or the like; but to go into the middle of a room, and endeavour to ſtand or ſit upon the beſt Non-conductor that can be found at hand, as an old chair, a ſtool, &c. "It "is ſtill ſafer (ſays Dr. FRANKLIN) to "bring two or three matraſſes or beds into "the middle of the room, and, folding "them up double, put the chair upon "them; for, they not being ſo good Con-"ductors as the walls, the lightning will "not chooſe an interrupted courſe through "the air of the room and the bedding, "when it can go through a continued "better Conductor, the wall. But where "it can be had, a hammock or ſwinging "bed, ſuſpended by ſilk cords, equally "diſtant from the walls on every ſide, and "from the ceiling and floor above and be-"low, affords the ſafeſt ſituation a perſon "can have in any room whatever, and "what indeed may be deemed quite free "from danger of any ſtroke by lightning."

If a ſtorm was to happen whilſt a perſon is in the open fields, and far from any building, the beſt thing he can do is to retire within a ſmall diſtance of the higheſt tree or trees he can get at; he muſt by no means go quite near them, but ſhould ſtop at about fifteen or twenty feet from their outermoſt branches; for if the lightning ſhould fall thereabout, it will very probably ſtrike the trees; and in caſe a tree was to be ſplit, he is ſafe enough at that diſtance from it.

In regard to the other great uſe of Electricity, *viz.* its application as a medicine, there have been many opinions *pro* and *contra*, and the reputation of medical Electricity has been very dubious and fluctuating; owing to the exaggerations, the miſtakes, the prejudices, and the intereſt of thoſe who have adminiſtered it in phyſical caſes. But after many experiments, and after overcoming the rooted prejudice of ſeveral phyſicians againſt medical Electricity, it has been clearly obſerved, that, when properly managed, it is an harmleſs remedy, which ſometimes inſtantaneouſly removes divers complaints, generally relieves and often perfectly cures various diſorders, ſome of which could not be removed by the utmoſt endeavours of phyſicians and ſurgeons.

It is an important remark, that Electricity, when properly managed, if it does not effect a cure, at leaſt it produces no bad effect; the few caſes in which it ſeems to have produced any harm, are of a doubtful nature. In order, however, to ſatisfy more fully the curioſity of the reader about this important ſubject, I ſhall here ſubjoin two caſes, in one of which, related by Dr. HART of Shrewſbury, the application of Electricity proved very pernicious; and the other is a moſt remarkable inſtance of its good effect. In regard to the firſt caſe, it is thought by ſome, that Electricity was injudiciouſly applied; but of the veracity and juſt treatment of the ſecond the reader can have no doubt, for it was executed by the celebrated Dr. WATSON, a gentleman, who is both an excellent phyſician, and one of the greateſt Electricians.

CASE I.

" A young girl, about ſixteen, whoſe
" right arm was paralytic, on being elec-
" trified the ſecond time, became univer-

“ ſally paralytic, and remained ſo about a
“ fortnight, when the increaſed palſy was
“ removed by medicines, which her caſe
“ indicated; but the firſt diſeaſed arm re-
“ mained as before: I ſhould have men-
“ tioned too, that this arm was greatly
“ waſted, in compariſon to the other.
“ However, notwithſtanding the former bad
“ accident, I had a mind to try the effect
“ of Electricity on her again; which we
“ renewed, and, after about three or four
“ days uſe, ſhe became the ſecond time
“ univerſally paralytic, and even loſt her
“ voice, and with difficulty could ſwallow.
“ This confirmed me in my opinion, that
“ the electrical ſhocks had occaſioned theſe
“ ſymptoms.—We therefore omitted it,
“ and the girl, though ſhe grew better of
“ her additional palſy, for ſo I call it, re-
“ mained as bad as before of her firſt *.”

CASE II.

A girl belonging to the Foundling Hoſpital, aged about ſeven years, being firſt

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* Phil. Tranſ. Vol. XLVIII.

ſeized with a diſorder occaſioned by the worms, was at laſt, by a univerſal rigidity of the muſcles, reduced to ſuch a ſtate, that her body ſeemed rather dead than alive. After other medicines had been ineffectually adminiſtered for about one month, ſhe was at laſt electrified intermittedly for about two months; after which time ſhe was ſo far recovered, that ſhe could, without pain, exerciſe every muſcle of her body, and perform every action as well as before ſhe had the diſtemper †.

The remarks made by philoſophers, relating to the effects of Electricity upon the human body in general, are the following; *viz.* that by electrization, whether poſitive or negative, the pulſe of a perſon is quickened, the number of pulſations being generally increaſed about one ſixth; and that glandular ſecretions, and the inſenſible perſpiration, are promoted, and often even reſtored, when they had been entirely obſtructed. Theſe effects may be proved by ſeveral experiments, independent of phyſical caſes; and I think there is nobody who will deny, that ſuch promotions are not only beneficial, but abſolutely neceſſary for removing ſeveral diſorders. It might be naturally ſuſpected, that the promotion of perſpiration, and of glandular ſecretion, were only the conſequence of the accelerated pulſation, and not the immediate effect of Electricity: but the contrary is eaſily proved, by obſerving, that in various caſes, the quickening of the pulſation by other means, independent of Electricity, as fear, exerciſe, &c. did not promote thoſe ſecretions nearly ſo much, if at all, as electrization; and alſo, that glandular ſecretion and perſpiration are often promoted by Electricity, when applied only to a particular part of the body, in which caſe it ſeldom, if ever, accelerates the pulſation.

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† Phil. Tranſ. Vol. LIII.

Hitherto it has not been diſcovered, that the electric fluid acts within the human body by any chymical property, as moſt medicines generally do; but its action, by which it produces the above-mentioned effects, may be conſidered merely as a mechanical ſtimulus; for it ſeems to act as ſuch, even

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within thoſe parts of the body, which, eſpecially when diſeaſed, are moſtly out of the reach of other remedies.

Formerly, in order to ſtimulate, or in general to apply Electricity to any diſeaſed part of the human body, ſtrong ſhocks, or at leaſt very pungent ſparks, were thought neceſſary; but at preſent it is very reaſonably eſtabliſhed, upon experience, that the greateſt electric powers which can be applied with good expectations, are exceedingly ſmall ſhocks and moderate ſparks, the proper force of which will be particularly deſcribed in the ſequel; but that in general, the moſt proper treatment is, to throw the fluid by means of a wooden point, as it is commonly called, or merely by a metallic point; in which laſt caſe, the perſon electrified feels only a gentle wind upon that part of the body towards which the point is directed.

By conſidering the above-mentioned effects of Electricity, one may naturally ſuſpect, that in caſes of preternatural diſcharges, the application of Electricity would be rather injurious than beneficial; becauſe in thoſe caſes the diſcharge is required to be ſuppreſſed, and not promoted. In reſpect to this important point, it has been obſerved, that if ſtrong ſhocks, or very pungent ſparks, are given to the patients afflicted with thoſe diſcharges, the diſeaſe is ſeldom cured, and on the contrary is often increaſed; but when only the fluid is drawn from the part, by means of a wooden point, or at moſt exceedingly ſmall ſhocks are adminiſtered, when the ſeat of the diſeaſe is more internal, then the diſcharge, &c. is at firſt generally promoted for a few days or hours, according to the nature of the diſeaſe and other circumſtances, but afterwards it leſſens by degrees, till it is quite cured. In cutaneous eruptions, the application of Electricity is generally attended with ſimilar effects.—The eruption firſt ſpreads farther for a ſhort time, and afterwards leſſens by degrees till it quite vaniſhes. From theſe obſervations it appears, that the application of Electricity, when judiciouſly managed, does not merely promote any diſcharge or circulation of fluids, but rather aſſiſts the *vis vitæ*, or that innate endeavour, by which nature tends to reſtore the ſound ſtate of the injured parts of a living animal.

It may perhaps be ever difficult to explain in what manner Electricity aſſiſts that natural endeavour; but experience ſhews the certainty of the fact, and with it we muſt be gratefully contented; for we may apply the effects to our wants, though we are ignorant of their cauſe, and of its mode of acting. When an electric ſhock is ſent through any part of the body, an inſtantaneous involuntary motion or convulſion is occaſioned, which ſhews that the muſcular fibres through which the ſhock is ſent, are expanded, or in ſome other manner convulſed. This involuntary motion, though not ſo ſtrongly, is occaſioned alſo by ſparks, and often even by drawing the fluid.—Farther, when a ſhock is ſent through or over ſeveral ſubſtances beſides the human body, a tremulous motion and an expanſion is evidently occaſioned, as may be ſhewn by many electrical experiments. Now all theſe obſervations may perhaps, in a manner, explain the action of Electricity upon the organized parts of an animal body, by comparing it with the tremulous motion given to pipes of any ſort, through which fluids are tranſmitted, in order to accelerate their paſſage, and to prevent any ſtoppage, which might ariſe from ſtagnation or accumulation of groſs bodies. Perhaps the reaſon why ſtrong ſhocks are generally hurtful, may be becauſe the irritation they give to the obſtructed parts, eſpecially when they are very minute and delicate, breaks their organization; the force being greater than thoſe parts can naturally bear.

Independent of undeniable practical obſervations, when it is only admitted that Electricity promotes natural ſecretions and circulation, which it certainly does, there follows, that its application muſt be beneficial in caſes of unnatural diſcharges; for in thoſe caſes the diſcharge is occaſioned by the obſtruction of the natural ways; but Electricity removes thoſe obſtructions, which is the ſame thing as to promote natural ſecretion and circulation; therefore, it muſt ſuppreſs the unnatural diſcharge, which can no longer exiſt when the natural courſe of the fluids has been reſtored.

With reſpect to diſeaſes in general, two ſtates of the affected parts ſhould be conſidered. The firſt is, the immediate and recent cauſe of the diſeaſe; and the ſecond ſtate is, the alteration of other parts, eſpecially ſolid, which is occaſioned by the long continuance of the firſt and principal cauſe; thus, for inſtance, the weakneſs or rupture of ſome veſſels within the body, may occaſion extravaſation of fluids, which is the firſt ſtate of the diſeaſe. Now if theſe extravaſated fluids continue in any part of the body, they will gradually occaſion a ſuppuration, an inflammation, or other ſymptoms, which vary according to innumerable circumſtances. This we may conſider as the ſecond ſtate of the diſeaſe. Again, when a palſy deprives a part of the body of its motion, the fleſhy and even the more ſolid parts, in proceſs of time, waſte and become disfigured; which is the effect of the obſtructed motion and circulation, and which we may therefore conſider as the ſecond ſtate of the diſeaſe; and ſo of the reſt. Now it has been obſerved, that the power of Electricity often removes the firſt ſtate of the diſorder; but the latter is very ſeldom cured by it. Indeed it ſeems almoſt impoſſible that a disfigured bone or deſtroyed organization ſhould be reſtored to its ſound ſtate by means of Electricity. Dr. FRANKLIN having electrified ſeveral paralytic perſons in America, obſerved that they were generally relieved for a few days at the beginning, but that they afterwards either did not mend, or relapſed into the ſtate, they were before the uſe of Electricity *. Here it muſt be obſerved, that thoſe paralyſies were moſtly of a long ſtanding, and alſo that the method practiſed by the Doctor, was to give ſtrong ſhocks, which we have already remarked to be rather prejudicial.

In general, the application of Electricity has been found to be of very little uſe in caſes of long ſtanding; becauſe, as we obſerved

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* See Dr. FRANKLIN's Philoſophical Letters, Papers, &c. and Dr. PRIESTLEY's Hiſt. of Electricity.

ſerved above, the more ſolid parts, by the long continuance of the diſorder, have undergone ſuch alteration, as cannot be reſtored by a mere ſtimulus, ſuch as the electric action is ſuppoſed to be. However, ſometimes diſeaſes of many years ſtanding have been perfectly cured by means of Electricity. In theſe caſes therefore, although there may be leſs hope of effecting a cure, it is not improper to apply the power of Electricity, which, when judiciouſly managed, does never produce any bad effects.

Hitherto, I do not know that any authentic facts have ſhewn any difference between the application of different kinds of Electricity, in medical caſes. Whether the patients be electrified by the prime Conductor, or the inſulated rubber of the uſual electrical machines, *viz.* whether they are electrified poſitively or negatively, ſeems to be quite indifferent.

In reſpect to the caſes in which Electricity may be applied; experience ſhews, that in general, all kinds of obſtructions, whether of motion, or circulation, or of ſecretion, are very often removed or alleviated by Electricity. The ſame may be alſo ſaid of nervous diſorders; both which include a great variety of diſeaſes. The application of Electricity has ſeldom intirely cured diſeaſes of a long ſtanding, although it generally relieves them. To perſons afflicted with the venereal diſeaſe, or to pregnant women, electrization has been thought to be pernicious; but my reader may be aſſured, that even in thoſe caſes it may be uſed without fear, if it is judiciouſly managed. When pregnant women are to be electrified for any diſorder, the ſhocks ſhould be abſolutely forbidden; and even when the other more gentle treatments are uſed, a conſtant attention ſhould be given to any phenomenon that may appear in the courſe of the electrization; the method of which ſhould be increaſed, diminiſhed, or ſuſpended, according as circumſtances may indicate.

Having thus given a ſummary view of the theory of medical Electricity, without entering into the detail of many phyſical caſes, I ſhall reſerve to ſay ſomething of the practical part, for the third part of this work; whilſt I muſt refer the reader, that is deſirous of knowing further particulars relating to medical Electricity, to my Eſſay on that ſubject, or to the works of others *.

CHAP. X.

Containing a compendious view of the principal properties of Electricity.

AFTER the laws hitherto eſtabliſhed in the ſcience of Electricity have been exhibited at large, and the particulars relating to each have been ſufficiently conſidered, it will not be amiſs to ſhow in how ſmall a compaſs thoſe laws may be reduced, and how narrow is the foundation of all that has hitherto been done.

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* Abundance of phyſical caſes, in which Electricity has been applied, may be met with in almoſt every writer on Electricity, but eſpecially in JALLABERT's Experimenta Electrica, LOVETT's Subtil Medium proved, WESLEY's Deſideratum, or Electricity made plain and uſeful, FERGUSON's Introduction to Electricity, and BECKET's Eſſay on Electricity. Some caſes in which Electricity has been ſucceſsfully applied for the amauroſis are alſo related in the 3d and 5th Vol. of the Medical Eſſays.

I doubt not but this recapitulation will prove very ſerviceable to thoſe, who are novices in Electricity, as, by getting in memory a few particulars, they will not only reconcile all that has been ſaid before, but alſo be enabled themſelves to explain moſt of the following experiments, and to underſtand the application of the hypotheſis, of which we ſhall next proceed to treat.

All the natural bodies are divided into two claſſes, *i. e.* Electrics and Conductors. Electrics are ſuch as may by ſome means be excited, ſo as to produce Electrical appearances; but Conductors are ſuch as cannot be excited by themſelves, *i. e.* without the interference of an Electric: further, electrical ſubſtances will not tranſmit Electricity, whereas the ſubſtance of Conductors is pervaded by it.

Electrics may be excited three ways, *i. e.* by friction, by heating and cooling, and by melting, or pouring one melted ſubſtance into another.

When two different bodies, except they are both Conductors, are rubbed together, they will both (provided that which is a Conductor be inſulated) appear electrified, and poſſeſſed of different Electricities; ſo when a piece of ſmooth glaſs is rubbed with an inſulated piece of leather, it acquires one kind of Electricity, called the vitreous, poſitive or plus Electricity; and the inſulated leather acquires the other, called the reſinous, negative or minus Electricity.

The difference between theſe two Electricities conſiſts principally in the appearances of their light, and in the phenomena of attraction and repulſion.

When the poſitive Electricity is entering a pointed body, it cauſes in general the appearance of a lucid ſtar or globule on that point; but the negative Electricity generally ſhows a lucid pencil of rays ſeeming to iſſue from the extremity of the pointed body.

Bodies, poſſeſſed of the ſame Electricity, repel each other; but bodies, poſſeſſed of different Electricities, attract each other.

Whenever bodies of any kind come within the ſphere of action of an electrified body, except they are very ſmall, and inſulated, they become actually poſſeſſed of the Electricity contrary to that of the electrified body, to which they are preſented.

No Electricity can be obſerved upon the ſurface of any electrified body, except that ſurface is contiguous to an Electric, which Electric can ſomehow or other acquire a contrary Electricity at a little diſtance. Otherwiſe,—no Electricity can appear upon the ſurface of any electrified body, except that ſurface is oppoſite to another body, which has actually acquired the contrary Electricity, and theſe contrarily electrified bodies are ſeparated by an Electric *.

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* On conſidering this principle, it may be aſked, why any Electricity can be obſerved upon the ſurface of an electrified body, that is inſulated at a conſiderable diſtance from other Conductors? Or, which is the

If the repulſion exiſting between bodies poſſeſſed of the ſame kind of Electricity be excepted, all the other electrical phenomena are occaſioned by the paſſage of Electricity from one body to another.

A conſiderable quantity of Electricity exiſts in the atmoſphere, and is certainly employed for ſome great purpoſes of nature.

the Electric, that is contiguous to the ſurface of an electrified Conductor, or excited Electric, and which has actually acquired a contrary Electricity at a little diſtance from the ſaid ſurface? To this queſtion is anſwered, that the air is in general the Electric, which is oppoſite to the ſurface of any electrified body, which being not a perfect Conductor, does eaſily acquire a contrary Electricity on a ſtratum of its ſubſtance, that is at a little diſtance from the electrified body; and in conſequence of this ſtratum, it acquires another ſtratum contrarily electrified, and at a little diſtance from the former; to this, other ſtrata ſucceed, alternately poſſeſſed of poſitive and negative Electricities, and decreaſing in power until they vaniſh, or come to the walls of the room, &c. Conſider the experiment of the glaſs tube, mentioned in the VIth chapter, which ſhows that, in general, when an Electric, ſufficiently denſe, is preſented to an electrified body, it acquires ſucceſſive zones, or ſtrata of poſitive and negative Electricity.

Hitherto Electricity has not been found concerned in any fermentation, evaporation, or coagulation, although the clouds, the rain, the hail, the ſnow and the fogs, are almoſt always electrified.

Theſe few laws, well conſidered, will be found to contain almoſt all that is known of the ſubject, and if properly applied, they may explain moſt of the experiments that follow.

Beſides what has been ſaid in this part of the preſent Treatiſe, there are ſeveral other maxims, rules, &c. to be known in Electricity; but as theſe moſtly reſpect the real practice, ſo they will be occaſionally inſerted in other places, that ſeem better adapted to their reception.

PART II.

THEORY OF ELECTRICITY.

CHAP. I.

The Hypotheſis of Poſitive and Negative Electricity.

IT is the buſineſs of Philoſophy to collect the hiſtory of appearances, and from theſe to deduce ſuch mechanical laws, as may either be themſelves of immediate uſe, or lead to the diſcovery of other facts more intereſting and neceſſary for the happineſs of human kind. After a number of ſuch conſtant appearances, which are called natural laws, have been eſtabliſhed, and confirmed by a ſufficient number of experiments, it is then proper to inveſtigate the cauſe of thoſe effects; which, if it is once diſcovered, and its mode of acting is aſcertained, puts an end to the trouble of experimental inveſtigation, and renders the application of its effects certain, and determinate.

Cauſes and effects are ſo intimately connected and dependent on each other, that throughout the ſyſtem of nature we every where diſcover a ſeries of energies, which whilſt they are depending on, and derived from, their preceding terms, are at the ſame time the cauſes of their ſucceeding ones. But what is the firſt cauſe of all the reſt, which being not the effect of any preceding, may be called the ſource of all, and the firſt term in the ſeries? In contemplating this ſource, the mind is loſt in wonder, and, after we are advanced a few ſteps, we find that a cloud obſtructs our further progreſs, and, from continuing our inquiry and contemplation, nothing more can be derived but an argument to prove the imbecillity and ſhortneſs of our underſtanding. This however is not the ſubject of the preſent Treatiſe; and all I meant to deduce is, that, after the laws of Electricity have been conſidered, it is neceſſary that we ſhould go a little further, and inveſtigate, if poſſible, the immediate cauſe of that property in nature, or conſider the moſt probable conjectures that have been offered on this ſubject: by the knowledge of which we may explain all the known electrical appearances, and adapt their effects to our purpoſes with ſomewhat more certainty and preciſion.

The vaſt number of hypotheſes that have been framed in explaining the electrical phenomena, from the infancy of the ſcience to the preſent time, may be eaſily imagined, by conſidering the great number of labourers, and the diſcoveries that have been produced without intermiſſion in this field of wonders. It would be not only an endleſs work to relate all the hypotheſes hitherto offered, but alſo an uſeleſs one, when they have been evidently contradicted by ſeveral experiments, and after they have all given place to the hypotheſis of a ſingle electric fluid, which generally goes under the name of Dr. FRANKLIN's. That although this hypotheſis explains all the known electrical appearances, it is however not a demonſtrable truth, but the moſt probable ſuppoſition, I confeſs; and, in order that a due diſtinction might be preſerved between the knowledge of facts, and the ſuppoſition of their immediate cauſe, I have ſeparated the former from the latter, and followed that method which ſeemed more philoſophical and inſtructive; but now to make further apologies for admitting this hypotheſis, at a time when numberleſs experiments ſpeak clear in its favour, would be doing an injury to the philoſophical world in general, and eſpecially to the ingenious philoſophers that propoſed and improved it. I ſhall therefore, without further preamble, lay it down as it is now commonly and reaſonably admitted; and ſhall uſe it in the explanation of the following experiments.

All the phenomena called Electrical are ſuppoſed to be effected by an inviſible ſubtile fluid exiſting in all the bodies of the earth. It is ſuppoſed alſo that this fluid is very elaſtic, *i. e.* repulſive of its own particles, but attractive of the particles of other matter.

When a body does not ſhow any electrical appearances, it is then ſuppoſed to contain its natural quantity of electric fluid (but whether that quantity bears any proportion to the quantity of matter in general, or not, is uncertain), and therefore that body is ſaid to be in its *natural*, or *non-electrified ſtate:* but if a body ſhows any electrical appearances, it is then ſaid to be electrified, and it is ſuppoſed that it has either acquired an additional quantity of electric fluid, or that it has loſt ſome of its natural ſhare. A body having received an additional quantity of electric fluid, is ſaid to be *overcharged*, or *poſitively electrified*; and a body that has loſt part of its natural quantity of electric fluid, is ſaid to be *undercharged*, or *negatively electrified.*

From hence it appears, why the terms *poſitive* and *negative*, or *plus* and *minus* Electricity came to be uſed; for the firſt ſignifies a real plus, or ſuperfluity, and the ſecond a real minus, or deficiency of the quantity of electric fluid proper to a body.

By this hypotheſis, which is analogous to the other phenomena of nature, the electrical appearances are eaſily explained, and there is not a ſingle experiment that ſeems to contradict it. Firſt it appears, that when an electric and a conducting ſubſtance are rubbed together, the Electricity is not then produced, but by the action of rubbing one body pumps, as it were, the electric fluid from the other*: hence, if one becomes overcharged with it, or poſitively electrified, the other muſt neceſſarily be undercharged, or electrified negatively, except its deficiency be ſupplied by other bodies communicating with it. From hence alſo appears the reaſon, why, when an Electric is rubbed with an inſulated rubber, it can acquire but little Electricity; becauſe in that caſe, the rubber, not communicating with other Conductors, can ſupply the Electric with only that ſmall quantity of fluid which belongs to itſelf, or which it collects from the contiguous air.

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* By what mechaniſm one body extracts the electric fluid from the other is not yet known. The celebrated Father BECCARIA ſuppoſes that the action of rubbing increaſeth the capacity of the Electric, *i. e.* renders that part of the Electric, which is actually under the rubber, capable of containing a greater quantity of electric fluid; hence it receives from the rubber an additional ſhare of fluid: which is manifeſted upon the ſurface of the Electric, when that ſurface is come out of the rubber; in which ſtate it loſes, or, as it were, contracts its capacity. Signior BECCARIA's experiment to prove this ſuppoſition is the following:—He cauſed a glaſs plate to be rubbed by a rubber applied on one ſide of the plate, while it was turning vertically; and holding at the ſame time a linen thread on the other ſide of the plate, juſt oppoſite to the rubber, he obſerved, that the thread was not attracted by that part of the glaſs which correſponded to the rubber, but by that which was oppoſite to the ſurface of the glaſs that had juſt come out of the rubber; which ſhows that the fluid, acquired by the glaſs plate, did not manifeſt its power until the ſurface of the glaſs was come out of the rubber. But, query, in what manner does the glaſs augment its capacity of holding the electric fluid by the action of the rubber? See Dr. FRANKLIN's Letters, &c. § 34.

Electric attraction is eaſily explained; for this does not exiſt, except between bodies differently electrified; which muſt certainly attract each other, on account of the attraction exiſting between the ſuperfluous electric fluid of the bodies electrified poſitively, and the undercharged matter of the bodies electrified negatively.

As to the repulſion exiſting between bodies poſſeſſed of the ſame Electricity; in order to underſtand its explanation thoroughly, the reader muſt be reminded of the principle mentioned in the preceding part, which is, that no Electricity, *i. e.* the electric fluid proper to a body, can either be augmented or diminiſhed upon the ſurface of that body, except the ſaid ſurface is contiguous to an Electric, which can acquire a contrary Electricity at a little diſtance; from whence it follows, that no Electricity can be diſplayed upon the facing ſurfaces of two bodies that are ſufficiently near one another, and both poſſeſſed of the ſame Electricity; for the air that lays between thoſe contiguous ſurfaces has no liberty of acquiring any contrary Electricity. This being premiſed, the explanation of electric repulſion becomes very eaſy. Suppoſe, for inſtance, that two ſmall bodies are freely ſuſpended by inſulated threads, ſo that when they are not electrified they may hang contiguous to one another. Now ſuppoſe thoſe bodies to be electrified either poſitively or negatively, and then they muſt repel one another; for either the increaſed, or the diminiſhed natural quantity of electric fluid in thoſe bodies, will endeavour to diffuſe itſelf equally over every part of the ſurfaces of thoſe bodies, and this endeavour will cauſe the ſaid bodies to recede from each other, ſo that a quantity of air may be interpoſed between their ſurfaces, ſufficient to acquire a contrary Electricity at a little diſtance from the ſaid ſurfaces.—Otherwiſe, if the bodies, poſſeſſed of the ſame Electricity,

city, do not repel each other, ſo that a ſufficient quantity of air may be interpoſed between their ſurfaces, the increaſed quantity of electric fluid, when the bodies are electrified poſitively, or the remnant of it, when the bodies are electrified negatively, by the above principle, cannot be diffuſed equally throughout, or over the ſurfaces of thoſe bodies; for no Electricity can appear upon the ſurfaces of bodies in contact, or that are very near one another. But the electric fluid, by attracting the particles of matter, endeavours to diffuſe itſelf equally throughout, or over the ſurfaces of thoſe bodies; therefore the ſaid bodies are, by this endeavour, forced to repel one another.

I think it is unneceſſary to inſiſt further upon the above explanation; for the principle, upon which it depends, ſeems univerſal and clear, ſo that it may be eaſily applied to explain electric repulſion in general, as well as the repulſion between the abovementioned two bodies.

The charging of coated glaſs, and other Electrics, as well as the other phenomena of Electricity, may alſo be eaſily accounted for by the above-mentioned hypotheſis of Electricity; but, I think it unneceſſary to enumerate, and account for all the particulars in this place, as we ſhall have occaſion to ſpeak of them in the explanation of the experiments in the third part.

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CHAP. II.

Of the Nature of the electric Fluid.

THE human mind, never ſatisfied, after the cauſe of ſome effects has been diſcovered, or only gueſſed at, attempts to inveſtigate ſome more intimate quality, and even the origin of that ſuppoſed cauſe, making further ſuppoſitions, and framing other hypotheſes, which, by the courſe of things, muſt certainly be leſs probable than the former. This unlimited endeavour to acquire knowledge is often too ridiculous to be purſued, on account of its abſtruſeneſs and uncertainty, eſpecially when the ſteps immediately preceding the ſubject in hand have but a ſmall degree of probability. It is from hence that Philoſophers have frequently ſpent a great deal of time, and trouble in attempting to diſcover the properties and cauſes of what exiſted only in their own imaginations. Sometimes, however, when a ſuppoſed exiſtence comes ſo very near to truth, that the moſt ſceptic Philoſopher heſitates not to confeſs the probability of it, or when he can invent no argument to evince the contrary, then it is not only allowable, but neceſſary for the buſineſs of Philoſophy, to purſue the enquiry further, and, if nothing elſe can be aſcertained, at leaſt to propoſe ſome further conjectures upon the former hypotheſis. This now is the caſe in the ſcience of Electricity; and after we have related the moſt plauſible hypotheſis as yet offered, *i. e.* that of a ſingle elaſtic fluid, we come in this place to conſider the eſſence of this fluid, in order, if poſſible, that we might attain to, at leaſt, ſome probable conjecture reſpecting its materials.

When nothing more than electric attraction and repulſion had been obſerved, Electricians ſuppoſed that theſe were effected by a kind of unctuous effluvia proceeding immediately from the electrified body; but when the light, the burning quality, the phoſphoreal ſmell, &c. was perceived to be produced by excited Electrics, then it was naturally ſuppoſed, that the electric fluid was of the ſame nature with fire. This opinion has prevailed much among ſeveral Philoſophers, and it is from hence, that the electric fluid has been commonly called Electric Fire. Beſides this ſuppoſed identity of the electric fluid, and the element of fire, there have been two other opinions concerning the eſſence of this fluid; it having been thought by ſome to be the ether of Sir ISAAC NEWTON, and by others (whoſe opinion ſeems to be the moſt probable) to be a fluid *ſui generis, i. e.* different from all other known fluids.

In order the more regularly to examine theſe conjectures, it will be neceſſary to premiſe ſomething in regard to the nature of fire, at leaſt ſo much as is ſufficient for the preſent purpoſe.

The element of fire may be conſidered in regard to its ſpring, to the different ſtates of its exiſtence, and to its effects. In regard to its origin it is commonly ſpecified under the names of Celeſtial, Subterraneous, and Culinary Fire; underſtanding by the firſt, that, which proceeds from the ſun, and, by being diſperſed throughout the univerſe, gives life, and motion to almoſt every thing that exiſts; by the ſecond, that, which is the cauſe of volcanos, hot ſprings, &c. and laſtly, under the name of Culinary Fire, underſtanding that, which is commonly produced upon the earth, by burning ſeveral ſubſtances. Theſe diſtinctions however are little if at all uſeful; for, whatever be the origin of fire, its effects are always the ſame.

In reſpect to the different ſtates of its exiſtence, the Chymiſts know only two; the firſt obvious one, and indeed that, to which only is given the name of Fire, is that actual agitation of the particles of that element, which produces the complex idea of lucid, hot, &c. that is commonly underſtood under the name *Fire*; and the other ſtate is the real principle of fire exiſting as a conſtituent principle in ſeveral, and perhaps all ſubſtances; or, that matter, whoſe particles, when agitated in a peculiar and violent manner, produce the common ſenſible fire.

This, which we may call fire in an unactive ſtate, is the *Phlogiſton* of the Chymiſts, and is that, which when united in a ſufficient quantity with other ſubſtances, renders them inflammable. That this principle does really exiſt, is beyond a doubt; we may tranſfer it from one body to another; we may render a body inflammable, which in its own nature is not ſo, by ſuperinducing on it the phlogiſton; and we may reduce a body naturally inflammable, to a ſubſtance not inflammable, by depriving it of its phlogiſton.

Now the electric fluid, as far as we can determine, bears but a very ſmall reſemblance to the above-mentioned two ſtates of fire; for although it exiſts in different bodies, as the phlogiſton, yet when we compare its other atrributes with thoſe of fire, we then immediately perceive it to be not the ſame, but a different principle. In the firſt place, if they were both the ſame thing, they ſhould be always together, and whenever ſuch a quantity of fire exiſts, there the ſame quantity of electric fluid ſhould be found: but this is contrary to experiments; for a piece of metal or other ſubſtance may acquire a great degree of heat without appearing at all electrified; and on the other hand, may be ſtrongly electrified without acquiring by it any ſenſible degree of heat, or any addition to its phlogiſton. Secondly, fire penetrates every known ſubſtance, and an exceedingly ſmall quantity of it is diffuſed alike throughout bodies of every kind; whereas the electric fluid pervades only Conductors *. Thirdly, the electric fluid goes through a very long Conductor in a ſpace of time almoſt inſtantaneous; but fire is very ſlowly propagated. I might enumerate ſeveral other improprieties attending this hypotheſis of the ſameneſs of fire and the electric fluid, but thoſe already mentioned are, I think, ſufficient to induce my readers to ſuppoſe otherwiſe.

Dr. PRIESTLEY, on obſerving that the electric exploſion, taken in different kinds of air, acts, in general, like other phlogiſtic

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* Here may be obſerved, that heat pervades more eaſily the ſubſtance of ſome good Conductors of Electricity; but the rule however is far from being general.

proceſſes, ſuppoſes that the electric matter either is, or contains, phlogiſton [†]. In regard to this, I would obſerve, that there is no neceſſity of ſuppoſing the electric matter either to be, or contain phlogiſton, on that account; for the phlogiſton, in this caſe, may, by the force of the electric exploſion, be extricated, either from the ſurface of the Conductors, between which the exploſion is taken, or from particles of heterogeneous matter floating in that air, in which the exploſion is made [§].

In regard to the ſimilarity between the effects of fire, and the effects of the electric fluid, it will be very obvious to remark, that although fire is in ſeveral inſtances produced by the electric fluid, yet we ſhould never confound the one with the other, and conſider them both as the ſame thing; for it is well known that friction produces fire, and it is by no means ſurpriſing that the electric fluid, by the rapidity of its motion, through ſubſtances, that in ſome manner obſtruct its paſſage, ſhould generate light, heat, rarefaction, and the other effects of fire *.

[†] Obſervations on different Kinds of Air, vol. II. ſec. XIII.

[§] See my Treatiſe on Air, &c. p. 433.

Mr. HENLY, in conſequence of ſeveral very intereſting experiments, that he has lately made, ſuppoſes, that, although the electric fluid may be neither phlogiſton nor fire, yet that it is a modification of that element, which, while in a quieſcent ſtate, is called Phlogiſton, and when violently agitated is called Fire. We conſtantly obſerve (ſays he) I. that if two bodies are rubbed together, which have an equal quantity of phlogiſton (which is the caſe with bodies of the ſame kind, as glaſs and glaſs, metal and metal, &c.) they acquire either very little, or no Electricity at all. II. That as one of the bodies has a greater quantity of phlogiſton than the other, ſo they acquire a greater quantity of Electricity, as when glaſs is rubbed with metal.

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* Here it is proper to obſerve, that the electric fluid ſhows no effects of fire, except when it goes through ſome medium that obſtructs its free paſſage.

III. That a certain degree of friction produces Electricity, and that *a more violent friction produces fire*, but no Electricity, as may be obſerved by rubbing together two pieces of baked wood, of glaſs, &c. IV. And that in general, bodies, poſſeſſed of a greater quantity of phlogiſton, give the electric fluid to bodies that have leſs of it, *i. e.* they acquire the negative Electricity, when rubbed with bodies that have a leſs quantity of phlogiſton *.

From theſe obſervations we gather, that the electric fluid, and fire, are produced by ſimilar operations, and are both extracted from bodies abounding with phlogiſton: and hence he concludes, that, the phlogiſton, the electric fluid, and fire, are only different modifications of the very ſame element; the firſt being its quieſcent ſtate of exiſtence, the ſecond its firſt active, and the laſt its more violent ſtate of agitation: like fermentation producing firſt wine, ſecondly vinegar, laſtly putrefaction.

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* Mr. HENLY, in order to try what Electricity different ſubſtances would acquire, inſulated them upon ſticks of ſealing wax, and rubbed them againſt his woollen coat, or waiſtcoat. In this manner he tried a vaſt number of vegetable, animal, mineral, and artificial ſubſtances; and he diſcovered a very remarkable law, which is, that ſuch ſubſtances, which have a great quantity of phlogiſton, as vegetable ſubſtances, and particularly the hot, aromatic plants and ſeeds, &c. *give* the electric fluid; that is, they acquire the negative Electricity when rubbed againſt woollen cloths; and, that ſuch ſubſtances, which have but little phlogiſton (as moſt animal ſubſtances) *acquire* the electric fluid from the ſaid cloths, *i. e.* they are electrified poſitively. See the Phil. Tranſ. for the year 1777.

I ſhall only obſerve further on this ingenious hypotheſis, in order to ſhow its great degree of probability, that it is ſo very analogous to the other operations of nature, and at the ſame time ſo clear, and ſimple, that I think it can hardly be diſregarded by the moſt prejudiced Philoſopher.

As to the identity of the Electric, and the ethereal fluid, it ſeems to me quite an improbable, or rather a futile, and inſignificant hypotheſis; for this ether is not a real, exiſting, but merely an *hypothetical fluid*, ſuppoſed by different Philoſophers to be endued with different properties, and to be an element of ſeveral principles. Some ſuppoſe it to be the element of fire itſelf, others make it the cauſe of attraction, others again derive animal ſpirits from it, &c.; but the truth is, that not only the eſſence, or properties, of this fluid, but even the reality of its exiſtence is abſolutely unknown.

According to Sir ISAAC NEWTON's ſuppoſition, this ether is an exceedingly ſubtle, and elaſtic fluid, diſperſed throughout all the univerſe, and whoſe particles repel the particles of other matter. But on this ſuppoſition the electric fluid is different from ether; for, although the former is ſubtle, and elaſtic, like the latter, yet (as Dr. PRIESTLEY obſerves) it is not repulſive like the ether, but attractive of all other matter.

CHAP.

CHAP. III.

Of the Nature of Electrics and Conductors.

THE remarkable difference exiſting between the two claſſes of bodies in regard to Electricity, *i, e.* Electrics and Conductors, naturally induces an Electrician to inquire what is that principle in bodies, or by what mechaniſm ſome ſubſtances become capable of tranſmitting the electric fluid, whilſt others are impervious to it?

In regard to the explanation of theſe two remarkable properties, there have been, as might be expected, ſeveral conjectures offered; but, except one probable hypotheſis, there is nothing as yet aſcertained. When the catalogue of Electrics and Conductors was very ſhort and imperfect, it was ſuppoſed that, the only two conducting principles were metals, and water; and that all ſubſtances were nearer, or further from the nature of a perfect Conductor, in proportion as they contained a greater or leſs quantity of the above principles in their compoſition. Wood, for inſtance, was ſuppoſed to be a Conductor only on account of the water it contained within its pores; accordingly, it was obſerved, that the greater quantity of moiſture the wood contained, the better Conductor it proved to be, and on the contrary, that it acted more like an Electric, in proportion as it was freed from its moiſture. But when water itſelf was obſerved to be a bad Conductor, and hot air, and charcoal to be good Conductors, eſpecially the latter, which ſubſtances, it is well known, contain no water nor metal, at leaſt not in ſuch a quantity as is ſufficient to change a non-conducting ſubſtance into a Conductor, then the former ſuppoſition was laid aſide, and another was offered by Dr. PRIESTLEY, in his ſecond volume of Obſervations on the different Kinds of Air [*], which ſeems to be well founded.

The Doctor, conſidering what the principle is, which Conductors poſſeſs in common,

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[*] Sec. XIV.

mon, and finding one of their common ingredients to be the phlogiſton, deduces from thence, that the conducting quality is abſolutely owing to the phlogiſton. "Had there been (ſays he) any phlogiſton "in water, I ſhould have concluded, that "there had been no conducting power in "nature; but in conſequence of ſome "union of this principle with ſome baſe. "In this, metals and charcoal exactly "agree:—while they have the phlogiſton, "they conduct; when deprived of it, they "will not conduct."

And in a note to this paragraph, he ſubjoins:

"Having ſince found, that long agitation "in the pureſt water injures air, ſo that "a candle will not burn in it afterwards, "which is preciſely the effect of all phlogiſtic proceſſes, I now conclude that the "maxim, ſuggeſted in this paragraph, is "univerſally true."

This hypotheſis ſeems very ingenious and probable; and, till any other more plauſible be offered, or experiments contradict it, I think we may ſafely make uſe of it in purſuing our electrical inveſtigations, and endeavour to reconcile to it the phenomena already diſcovered in Electricity.

CHAP. IV.

Of the Place occupied by the electric Fluid.

BEFORE we quit the hypothetical part of this Treatiſe, it may be proper to ſay ſomething concerning the reſidence of the electric fluid, either natural to a body, or ſuperinduced on it. That the electric fluid, proper to a body when in its natural ſtate, is equally diffuſed throughout all its ſubſtance, I think no one will deny; becauſe that fluid is attractive of the particles of all other matter, and the particles of other matter are attractive of the electric fluid; and as this attraction is in proportion to the quantity of homogeneous matter, any quantity of matter will certainly attract a quantity of electric fluid proportionable to itſelf; therefore, the electric fluid muſt be equally diffuſed throughout all the parts of that portion of matter. This propoſition, however, will take place only in ſpeaking of Conductors; for it is founded upon the ſuppoſition, that the electric fluid, proper to a body in its natural ſtate, does freely pervade that ſubſtance; but whether this is a fact reſpecting Electrics, or not, hath not hitherto been aſcertained. As far as may be judged from experiments, I ſhould ſuppoſe this rule to hold good with Electrics alſo; and my ſuppoſition is founded upon the following reaſoning:—All the Electrics, when made very hot, become Conductors *; in that ſtate, therefore, the above rule muſt hold good, *i. e.* the electric fluid, proper to their quantity of matter, muſt be equally diffuſed throughout their ſubſtance: and as all the Electrics in nature, before they became ſuch (we may ſuppoſe) were Conductors; in that ſtate they certainly had their proper ſhare of fluid. Now as they afterwards cool, and become Electrics, it ſhould ſeem that the change of their nature could not affect the equal diffuſion of the electric fluid, which took place whilſt they were in a conducting ſtate. In conſequence of this conſideration, the difference between a Conductor and a Non-conductor, in regard to their natural quantity of electric fluid, is, that in the former, the fluid may eaſily move, whereas in the latter, it is confined in its pores. But it may be aſked, whether a quantity of electric matter contains as much electric fluid as an equal quantity of conducting matter; a piece of roſin, for inſtance, when melted, does it contain more, leſs, or the ſame quantity, of electric fluid as when cold? To this queſtion I can give no ſatisfactory anſwer; for, by the experiments hitherto made, nothing certain has been determined. Dr. PRIESTLEY, in order to aſcertain this matter, made the following experiment:—He made a piece of glaſs red-hot (in which ſtate it is a Conductor) and placing it upon an inſulated piece of copper, left it in that ſituation till quite cold

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* As this propoſition has been found true in all the experiments hitherto made, I think it may be conſidered very properly, as a general law in the ſcience of Electricity.

(*i. e.* till it became an Electric); but in all the time of its cooling, no Electricity of any kind was perceived, either in the copper or glaſs; which would have certainly been the caſe, if the piece of glaſs had contained either more or leſs fluid when in an Electric, than when in a conducting ſtate*. This experiment ſeems to give a deciſive anſwer to the above queſtion; but when the experiments, mentioned in the firſt part, of melting an electric ſubſtance into another, and other facts of a ſimilar nature, are duly conſidered, they ſeem to make the anſwer again difficult §. It muſt therefore be confeſſed, that this matter remains as yet unſettled; and nothing but further experiments, and the diſcovery of other facts, can determine any thing ſatisfactory about it.

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* Hiſtory of Electricity, p. 716.—Experiments of a ſimilar nature are met with in BECCARIA's Electriciſmo Artificiale.

§ The wax-chandlers, in forming their maſs into ſticks, &c. find it ſo ſtrongly attractive of duſt, &c. that they are obliged to uſe great caution in keeping it at a ſufficient diſtance from the charcoal fire, over which they work, leſt it ſhould (as ſometimes happens) cover itſelf with aſhes, and thus ſpoil the work.

In reſpect to the place occupied by the electric fluid ſuperinduced on a body, it has been thought, by ſeveral ingenious perſons, that, when a body is electrified, all the ſuperfluous fluid, or all the deficiency of it, in caſe the body is electrified negatively, reſides as a kind of atmoſphere all around the body; to this atmoſphere they attribute the phoſphoreal ſmell, and that tickling ſenſation produced by an excited Electric; and they even ſuppoſe that theſe atmoſpheres may be made viſible. But to this aſſertion it is anſwered by others, that if the Electricity communicated to a body did reſide round it like an atmoſphere, it ſhould certainly repel the air contiguous to that body; but this is not the reſult of experiments; for it has been found that the electric atmoſphere, however denſe, if it does at all exiſt, has no effect upon the air contiguous to the electrified body, nor has the motion of the air, even a violent wind, any effect upon the atmoſphere. In regard to the above-mentioned ſenſations of phoſphoreal ſmell, &c. it is thought that they are only occaſioned by the electric fluid entering or going out of the ſkin in a very ſubdivided manner.

From what may be deduced from experiments, it appears that, although the electric fluid is tranſmitted through the ſubſtance of Conductors, yet no communicated Electricity can be obſerved within a ſufficiently narrow cavity of an electrified body; beſides, if two bodies of the ſame ſize and figure, but of different denſities, are electrified together, and afterwards ſeparated, they will acquire each the ſame quantity of Electricity, *i. e.* the Electricity that they acquire will be proportional to their ſurfaces, and not to their reſpective quantities of matter.

We may laſtly conclude, that the Electricity communicated to a body, lies not diffuſed throughout the ſubſtance of that body, but on that ſurface of it which is contiguous to a free Electric, *i. e.* to an Electric, that is not ſurrounded by an homologous Electricity.

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PART III.

PRACTICAL ELECTRICITY.

CHAP. I.

Of the electrical Apparatus in general.

HITHERTO we have treated of Electricity only theoretically, having noted what has been found uniformly certain relative to this ſubject, and having exhibited a view of the moſt probable conjectures offered in explanation of electrical appearances; but Electricity being a ſcience, that requires a more practical management, than perhaps any other branch of natural philoſophy, it is neceſſary, that we ſhould now treat of it practically, and give the beſt directions we are able, both in regard to the conſtruction of the neceſſary apparatus, and to the performance of the experiments, not only requiſite in proving the foregoing Propoſitions,

tions, but ſuch alſo as are pleaſing and entertaining.

In this part of my work the reader will perhaps find more novelty, than he expects; for, conſidering the number of books that have been lately publiſhed on this ſubject, one would imagine that all the experiments poſſible to be exhibited with an electrical machine, and its appendages, have already been deſcribed. The caſe however is much the contrary; for not only the old experiments have been diverſified, but a variety of new ones have been invented, and even the principal part of the apparatus has undergone ſeveral changes, and improvements.

In order the more regularly to proceed in the deſcription of the electrical apparatus, it will not be improper to divide its parts into three claſſes; conſidering in the firſt, the inſtruments neceſſary to produce Electricity; in the ſecond, thoſe proper to accumulate, retain, and employ it; and laſtly, thoſe neceſſary to meaſure its quantity, and aſcertain its quality.

The principal inſtrument to produce Electricity, is the electrical Machine, *i. e.* a machine capable by any means of exciting an Electric, ſo as to produce electrical appearances. The conſtruction of thoſe machines, from their firſt invention to the preſent time, has undergone ſo many changes, and their forms have been ſo much varied, that it would be very difficult, and even tedious, to deſcribe thoſe only which are moſt frequently in uſe. Every maker, and almoſt every Electrician conſtructs his own machines in a manner different from the reſt; and, as new facts, or long practice points out ſome imperfections, the Electrician is ready to contrive a new method to correct the preceding errors. Indeed the rapid advance of the ſcience is moſtly owing to this change, and variety of conſtructions; for whether caſual, or deſigned, a new conſtruction has generally either produced ſome diſcovery of importance, or expoſed ſome defect in the apparatus, and management of the ſame.

That the reader may be left at the liberty of chooſing the form of his machine, I ſhall in this chapter lay down the moſt neceſſary rules to conſtruct electrical machines in general; and ſhall reſerve for the next chapter the particular deſcription of ſome machines, that are the moſt uſeful, and which contain all the improvements hitherto made.

The principal parts of the machine are the Electric, the moving Engine, the Rubber, and the prime Conductor, *i. e.* an inſulated Conductor, which immediately receives the Electricity from the excited Electric.

The Electric was formerly uſed of different ſubſtances, as glaſs, roſin, ſulphur, ſealing-wax, &c.; and of different forms, as cylinders, globes, ſpheroids, &c. This diverſity then obtained on two accounts, firſt, becauſe it was not aſcertained, which ſubſtance or form would anſwer beſt, and ſecondly, on account of producing a negative, or poſitive Electricity, at the pleaſure of the operator; for before the Electricity of the inſulated rubber was diſcovered, ſulphur, rough glaſs, or ſealing-wax, was generally uſed for the negative Electricity. At preſent, ſmooth glaſs only is uſed; for when the machine has an inſulated rubber, the operator may produce poſitive or negative Electricity at his pleaſure, without changing the Electric. In regard to the form of the glaſs, thoſe commonly uſed at preſent are globes, and cylinders. The moſt convenient ſize for a globe, is from nine to twelve inches diameter: they are made with one neck, which is cemented * to a ſtrong braſs cap, in order to adapt them to a proper frame. The cylinders are made with two necks; they are uſed to the greateſt advantage without any axis, and their common ſize is from four inches diameter and eight inches long, to twelve inches diameter and two feet

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* The beſt cement for electrical purpoſes is made with two parts of roſin, two of bees-wax, and one of the powder of red okre. Theſe ingredients are melted, and mixed together in any veſſel over the fire; and afterwards kept for uſe. This kind of cement ſticks very faſt, and is much preferable to roſin only, as it is not ſo brittle, and at the ſame time inſulates equally well.

long; ſome have been made in London even of twenty-one inches in diameter. The glaſs generally uſed is the beſt flint, though it is not yet abſolutely determined, which kind of metal is the beſt for electrical globes, or cylinders. The thickneſs of the glaſs ſeems immaterial, but perhaps the thinneſt is preferable. It has often happened, that glaſs globes, and cylinders, in the act of whirling, have burſt in innumerable pieces, with great violence, and with ſome danger to the by-ſtanders. Thoſe accidents are ſuppoſed to happen when the globes, or cylinders, after being blown, are ſuddenly cooled. It will therefore be neceſſary to enjoin the workman to let them paſs gradually, from the heat of the glaſs-houſe, to the atmoſpherical temperature.

It has been long queſtioned whether a coating of ſome electric ſubſtance, as roſin, turpentine, &c. on the inſide ſurface of the glaſs, has any effect to increaſe its electrical power; but now it ſeems pretty well determined, that if it does not increaſe the power of a good glaſs globe or cylinder, at leaſt it does conſiderably improve a bad one. I have ſeveral times put a coating of roſin on the inſide ſurface of phials and tubes, and have conſtantly found, that the worſt of them received ſome improvement by it.

The moſt approved compoſition for lining glaſs globes, or cylinders, is made with four parts of Venice turpentine, one part of roſin, and one part of bees-wax. This compoſition muſt be boiled for about two hours over a gentle fire, and muſt be kept ſtirring very often: afterwards it is left to cool, and reſerved for uſe. When a globe or cylinder is to be lined with this mixture, a ſufficient quantity of it is to be broken into ſmall pieces, and introduced into the glaſs; then, by holding the glaſs near the fire, the mixture is melted, and equally ſpread over all its internal ſurface, to about the thickneſs of a ſixpence. In this operation care muſt be taken, that the glaſs be made hot gradually, and be continually turned, ſo as to be heated equally in all parts, otherwiſe, it is apt to break in the operation.

In reſpect to the Engine which is to give motion to the Electric, multiplying wheels have been generally uſed; which, properly adapted, might give the Electric a quick motion, while they are conveniently turned by a winch. The uſual method is, to fix a wheel on one ſide of the frame of the machine, which is turned by a winch, and has a groove round its circumference. Upon the braſs cap of the neck of the glaſs globe, or one of the necks of the cylinder, a pulley is fixed, whoſe diameter is about the third or fourth part of the diameter of the wheel; then a ſtring or ſtrap is put over the wheel and the pulley, and by theſe means, when the winch is turned, the globe or cylinder makes three or four revolutions, for one revolution of the wheel. There is an inconvenience generally attending this conſtruction, which is, that the ſtring is ſometimes ſo very ſlack, that the machine cannot work. To remedy this inconvenience, the wheel ſhould be made moveable with reſpect to the Electric, ſo that by means of a ſkrew it might be fixed at the proper diſtance; or elſe the pulley ſhould have ſeveral grooves of different radiuſes on its circumference.

It has been cuſtomary with ſome, to turn the cylinder ſimply with a winch, without any accelerated motion; but that ſeems not ſufficient to produce the greateſt electric power, the glaſs is capable of giving; for the globe or cylinder ſhould properly make about ſix revolutions in a ſecond, which is more than can be conveniently done with the winch only. This method however, on account of its ſimplicity, and eaſy conſtruction, ſhould not be diſregarded, and it may be conveniently uſed, when no very great power is required.

Inſtead of the pulley and the ſtring, as above deſcribed, a wheel and pinion, or a wheel, and an endleſs ſkrew, has been alſo uſed. This conſtruction anſwers perhaps as well as any other; but, it muſt be conſtructed with great nicety, otherwiſe, it is apt to make a diſagreeable rattling, and without frequent oiling, ſoon wears away by the great friction of its own parts.

The next thing belonging to the Electrical machine, neceſſary to be deſcribed, is the rubber, which is to excite the Electric. The rubber, as it is now made, is nothing more than a ſilk cuſhion ſtuffed with hair; and over this cuſhion is put a piece of leather, on which ſome amalgam * has been rubbed, ſo as to ſtick as faſt as poſſible to the leather. Some time ago it was generally uſed, and it is now cuſtomary alſo, to make the rubber of red baſil ſkin ſtuffed with hair; but the ſilk one, as above deſcribed (which is an improvement of Dr. NOOTH) is much preferable. If this ſilk cuſhion, on account of adapting it to the ſurface of the glaſs, is to be fixed upon a metal plate, then care ſhould be taken to make the plate free from ſharp points, edges, or corners, and it ſhould be as much as poſſible concealed, or covered

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* The amalgam has been found to excite ſmooth glaſs moſt powerfully. Any metal, diſſolved in quick-ſilver, will perhaps do equally well, but the amalgam that has been generally uſed, is made with two parts of quick-ſilver and one of tin-foil, with a ſmall quantity of powdered chalk, mixed together until it becomes a maſs, like paſte. An amalgam made with one part of zinc, and four or five parts of mercury, anſwers ſtill better, as diſcovered by Dr. HIGGINS. *Moſaic gold* may alſo be uſed.

with ſilk. In ſhort, to conſtruct the rubber properly, it muſt be made in ſuch a manner, that the ſide of it, which the ſurface of the glaſs enters in whirling, may be as perfect a Conductor, as it can be made, in order to ſupply Electricity as quick as poſſible; and the oppoſite part ſhould be as much a Non-conductor as poſſible, in order that none of the fluid accumulated upon the glaſs, may return back to the rubber, which has been found by experiment to be the caſe, when the rubber is not made in a proper manner. For which reaſon a piece of ſilk is alſo added to the extremity of the leather.

The rubber ſhould be ſupported by a ſpring, by which means it may eaſily ſuit any inequalities that may be found on the ſurface of the glaſs; and by a ſkrew it may be made to preſs harder or ſofter, as occaſion may require. It ſhould alſo be inſulated in whatever manner is moſt convenient; for whenever inſulation is not required, a chain or wire, &c. may be occaſionally hung upon it, and thus communicate with the earth, or with any other body, at pleaſure; whereas, when there is not a contrivance for inſulating the rubber, many of the moſt curious experiments in Electricity will never be performed with the machine.

We come now to conſider the prime Conductor, or firſt Conductor, which is nothing more than an inſulated conducting ſubſtance furniſhed with one or more points at one end, in order to collect the Electricity immediately from the Electric. When the Conductor is of a moderate ſize, it is uſual to make it of hollow braſs, but when it is very large, then, on account of the price of the materials, it is made of paſte-board, covered with tin-foil, or gilt paper. The Conductor is generally made cylindrical; but let the form be what it will, it ſhould always be made perfectly free from points, or ſharp edges; and if holes are to be made in it, which on many accounts are very convenient, they ſhould be well rounded, and made perfectly ſmooth. Further, that end of the prime Conductor, which is at the greateſt diſtance from the Electric, ought to be made larger than the reſt, as the ſtrongeſt exertion of the electric fluid, in eſcaping from the Conductor, is always at that end.

It has been conſtantly obſerved, that the larger the prime Conductor is, the longer, and denſer ſpark can be drawn from it; and the reaſon of this is, that the quantity of Electricity, diſcharged in a ſpark, is nearly proportional to the ſize of the Conductor; on this account the prime Conductor is now made much larger, than what was formerly uſed. Its ſize, however, may be ſo large, that the diſſipation of the Electricity from its ſurface, may be greater than what the Electric can ſupply; in which caſe ſo large a Conductor would be nothing more than an unwieldy, and diſagreeable incumbrance.

Before we quit the Electrical machine, it ſhould be obſerved, that, beſides the abovementioned parts, it is neceſſary to have a ſtrong frame to ſupport the Electric, the rubber, and the wheel. The prime Conductor ſhould be ſupported by ſtands with pillars of glaſs, or baked wood, and not by ſilk ſtrings, which admit of continual motion. In ſhort, the machine, the prime Conductor, and any other apparatus actually uſed, ſhould be made to ſtand as ſteady as poſſible, otherwiſe many inconveniences will ariſe.

Beſides the Electrical machine, the Electrician ſhould be provided with glaſs tubes of different ſizes, a pretty large ſtick of ſealing-wax, or a glaſs tube covered with ſealing-wax, for the negative Electricity. He ſhould at leaſt not be without a glaſs tube about three feet long, and one inch and a half in diameter. This tube ſhould be cloſed at one end, and at the other end ſhould have fixed a braſs cap with a ſtop-cock, which is uſeful in caſe it ſhould be required to condenſe, or rarefy the air within the tube.

The beſt rubber for a tube of ſmooth glaſs is the rough ſide of black oiled ſilk, eſpecially when it has ſome amalgam rubbed upon it; but the beſt rubber for a rough glaſs tube, a ſtick of baked wood, ſealing-wax, or ſulphur, is ſoft new flannel.

The inſtruments neceſſary for the accumulation of Electricity, are coated Electrics, among which, glaſs coated with Conductors obtains the principal place; on account of its ſtrength it may be formed into any ſhape, and it will receive a very great charge. The form of the glaſs is immaterial with reſpect

to

to the charge it will contain; its thickneſs only is to be conſidered, for the thinner it is, the higher charge it is capable of receiving; but it is at the ſame time more ſubject to be broken by the force of electric attraction; for this reaſon, therefor , a thin coated jar, or plate may be uſed very well by itſelf, and it is very convenient for many experiments; but when large batteries are to be conſtructed, then it is neceſſary to uſe glaſs a little thicker, and care ſhould be taken to have them perfectly well annealed. If a battery is required of no very great power, as containing about eight or nine ſquare feet of coated glaſs, I ſhould recommend to make uſe of common pint, or half-pint phials, ſuch as apothecaries uſe. They may be eaſily coated with tin-foil, ſheet-lead, or gilt-paper on the outſide, and braſs-filings on the inſide; they occupy a ſmall ſpace, and, on account of their thinneſs, hold a very good charge. But when a large battery is required, then theſe phials cannot be uſed, for they break very eaſily; and for that purpoſe cylindrical glaſs jars, of about fifteen inches high, and four or five inches in diameter, are the moſt convenient. One large jar anſwers better than ſeveral ſmall ones, becauſe the diſſipation of the electric fluid over the uncoated part is not ſo conſiderable in the former as in the latter caſe. But then, if a large jar breaks, the loſs is much more conſiderable.

When glaſs plates or jars, having a ſufficiently large opening, are to be coated, the beſt method is to coat them with tin-foil on both ſides, which may be fixed upon the glaſs with varniſh, gum-water, bees-wax, &c.; but in caſe the jars have not an aperture large enough to admit the tin-foil, and an inſtrument to adapt it to the ſurface of the glaſs, then, braſs filings, ſuch as are ſold by the pin-makers, may be advantageouſly uſed, and they may be ſtuck with gum-water, bees-wax, &c. but not with varniſh, for this is apt to be ſet on fire by the diſcharge, as will appear in the latter part of this work. Care muſt be taken that the coatings do not come very near the mouth of the jar, for that will cauſe the jar to diſcharge itſelf. If the coating is about two inches below the top, it will in general do very well; but there are ſome kinds of glaſs, eſpecially tinged glaſs, that, when coated and charged, have the property of diſcharging themſelves more eaſily than others, even when the coating is five or ſix inches below the edge *. There is another ſort of glaſs, like that of which Florence flaſks are made, which, on account of ſome unvitrified particles in its ſubſtance, is not capable of holding the leaſt charge; on theſe accounts, therefore, whenever a great number of jars are to be choſen for a large battery, it is adviſeable to try ſome of them firſt, ſo that their quality, and power may be aſcertained.

Electricians have often endeavoured to find ſome other Electric, which might anſwer better than glaſs for this purpoſe, at leaſt be cheaper; but, except Father BECCARIA's method, which may be uſed very well, I do not find that any remarkable diſcovery has been made relating to this point.

10 Father BECCARIA took equal quantities of very pure colophonium, and powder of

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* When a jar diſcharges itſelf, the electric fluid runs from the inſide to the outſide coating over the ſurface of the glaſs, where it leaves an indelible mark all along its path, which is moſtly in a *zig-zag* form.

marble ſifted exceedingly fine, and kept them in a hot place for a conſiderable time, where they became perfectly free from moiſture; he then mixed them, and melted the compoſition in a proper veſſel over the fire, and when melted poured it upon a table, upon which he had previouſly ſtuck a piece of tin-foil, reaching within two or three inches of the edge of the table; this done, he endeavoured with a hot iron to ſpread the mixture all over the table as equally as poſſible, and to the thickneſs of one tenth of an inch; he afterwards coated it with another piece of tin-foil reaching within about two inches of the edge of the mixture; in ſhort, he coated a plate of this mixture like a plate of glaſs. This coated plate, from what he ſays, ſeems to have had a greater power than a glaſs plate of the ſame dimenſions, even when the weather was not very dry: and, if it is not ſubject to break very eaſily by a ſpontaneous diſcharge, I think it may be very conveniently uſed; for it doth not very readily attract moiſture, and conſequently may hold a charge of Electricity better, and longer than glaſs: beſides, if broken, it may be repaired by a hot iron;

but glaſs, when broke, can never be repaired.

When a jar, a battery, or in general, a coated Electric, is to be diſcharged, the operator ſhould be provided with an inſtrument called the diſcharging Rod, which conſiſts of a metal rod ſometimes ſtraight, but more commonly bended in the form of a C: they are made alſo of two joints, ſo as to open like a kind of compaſſes. This rod is furniſhed with metal knobs at its extremities, and has a non-conducting handle, generally of glaſs or baked wood, faſtened to its middle. When the operator is to uſe this inſtrument, he holds it by the handle, and, touching one of the coated ſides of the charged Electric with one knob, and approaching the other knob to the other coated ſide, or ſome conducting ſubſtance communicating with it, he completes the communication between the two ſides, and diſcharges the Electric.

The inſtruments to meaſure the quantity, and aſcertain the quality of Electricity, are commonly called *Electrometers*; and they are of four ſorts, 1ſt. the ſingle Thread, 2d. the

Cork, or Pith-balls, 3d. the Quadrant, and 4th. the diſcharging Electrometer *. But a particular deſcription of the ſame will be found in the third chapter of this work.

Beſides the apparatus above deſcribed, there are ſeveral other inſtruments uſeful for various experiments, but theſe will be deſcribed occaſionally. The Electrician, however, ought to have by him not only a ſingle coated jar, a ſingle diſcharging rod, or in ſhort, only what is neceſſary to perform the common experiments; but he ſhould provide himſelf with ſeveral plates of glaſs, with jars of different ſizes, with a variety of different inſtruments of every kind, and even tools for conſtructing them; in order that he may readily make ſuch new experiments, as his curioſity may induce him to try, or that may be publiſhed by other ingenious perſons, who are purſuing their reſearches in this branch of philoſophy.

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* The ſecond ſort of Electrometer, *i. e.* the cork-balls Electrometer, was invented by Mr. CANTON: the diſcharging Electrometer was invented by Mr. LANE, and another, on a different principle, by Mr. RINNERSLEY: and the quadrant Electrometer, which is of lateſt invention, is a contrivance of Mr. HENLY.

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CHAP. II.

The deſcription of ſome particular electrical Machines.

IN this chapter I ſhall preſent the reader with the particular deſcription of three electrical machines, which, I think, will be very acceptable after the general account of their conſtruction, which has already been given. The firſt of theſe is that deſcribed by Dr. PRIESTLEY, in his Hiſtory of Electricity *; where a drawing of the ſame may be ſeen, and which, on account of its extenſive uſe, may be deſervedly called a univerſal electrical Machine.

The baſis of this machine conſiſts of two oblong boards, which are kept in a ſituation parallel to one another, about four inches aſunder, by two ſmall pieces of board properly adapted to that purpoſe. Theſe boards, when ſet horizontally upon a table, and there fixed by faſtening the lower of them with iron cranks, form the ſupport of two perpendicular pillars of baked wood, and of the rubber of the machine. One of the pillars, together with the ſpring ſupporting the rubber, ſlides in a groove, which reaches almoſt the whole length of the upper board, and, by means of ſcrews, may be placed at any required diſtance from the other pillar, which is fixed, being let through a mortice in the upper board, and ſtrongly faſtened to the lower. In theſe two pillars are ſeveral holes for the admittance of the ſpindles of different globes, and, as they may be ſituated at any diſtance from one another, they may be adapted to receive not only globes, but alſo cylinders, or ſpheroids of different ſizes. In this machine, ſays Dr. PRIESTLEY, more than one globe or cylinder may be uſed at once, by fixing them one above the other in the different holes of the pillars; and by adapting to each a proper pulley, they may be whirled all at once, and their power united, in order to increaſe the Electricity *; but in this conſtruction I do not

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* Part V. ſec. II.

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* When ſeveral globes are uſed at once, and their power is united, it has been found by experiment, that the Electricity does not increaſe in proportion to their number,

not think that different rubbers can be conveniently applied to them all; which is a capital imperfection.

" The rubber conſiſts of a hollow piece
" of copper, filled with horſe-hair, and
" covered with a baſil ſkin. It is ſupported
" by a ſocket, which receives the
" cylindrical axis of a round and flat piece
" of baked wood, the oppoſite part of
" which is inſerted into the ſocket of a
" bent ſteel ſpring. Theſe parts are eaſily
" ſeparated, ſo that the rubber, or the piece
" of wood that ſerves to inſulate it, may
" be changed at pleaſure. The ſpring
" admits of a two-fold alteration of poſition.
" It may be either ſlipped along the
" groove, or moved in the contrary direction"
(the groove being wider than the ſcrew which faſtens the ſpring), " ſo
" as to give it every deſirable poſition with
" reſpect

number, although it is more, than what may be produced by a ſingle globe. However, as the friction, and the difficulty of working the machine, increaſes in proportion to the number of globes or cylinders, ſo I think that one good large cylinder is preferable to many of them.

" reſpect to the globe or cylinder; and it " is, beſides, furniſhed with a ſcrew, " which makes it preſs harder or lighter, " as the operator chooſes."

The wheel of this machine is fixed to the table; it has ſeveral grooves, for admitting more ſtrings than one, in caſe that two or three globes, or cylinders are uſed at a time; and as it is diſengaged from the frame of the machine, the latter may be ſkrewed at different diſtances from the former, and thus ſuited to the variable length of the ſtring.

The prime Conductor is of hollow copper, made in the ſhape of a pear, ſituated with its neck upwards, and with its bottom or rounder part upon a ſtand of baked wood; and an arched wire proceeds from its neck, having an open ring at its end, in which ſome ſmall pointed wires are hung, that by playing lightly upon the Electric collect the electric fluid from it. This form of prime conductor is, however, very improper.

This machine, notwithſtanding that it has ſeveral imperfections, is yet a very good contrivance; but, except different globes, or cylinders, or ſeveral of thoſe at once, are required to be uſed, I think a great deal of the work may be ſpared, and the machine might be made more ſimple, and conciſe.

Next to Dr. PRIESTLEY's machine, I ſhall deſcribe another, which, for its ſimplicity, and conciſeneſs, makes a fine contraſt with the former.

This machine conſiſts of a circular glaſs plate, about one foot diameter, which is turned vertically by a winch fixed to the iron axis that paſſes through its middle; and it is rubbed by four cuſhions, each about two inches long, ſituated at the oppoſite ends of the vertical diameter.

The frame conſiſts of a bottom board, about a foot ſquare, or a foot long and ſix inches broad, which, when the machine is to be uſed, may be faſtened by an iron crank to the table. Upon this board two other ſlender, and ſmaller ones are raiſed, which lie parallel to one another, and are faſtened together at their top by a ſmall piece of wood. Theſe upright boards ſupport in their middle the axis of the plate, and to them the rubbers are faſtened.

The Conductor is of hollow braſs, and from its extremities branches are extended, which coming very near the extremity of the glaſs, collect the Electricity from it.

The power of this machine is perhaps more than a perſon would judge by looking at it. It may be objected, that this conſtruction will not eaſily admit of the rubbers being inſulated, nor conſequently be adapted to a great variety of experiments; but at the ſame time it muſt be allowed, that it is very portable, that it is not very liable to be out of order, and that it has a power ſufficiently ſtrong for ſeveral purpoſes; on which account it may be conveniently uſed. Theſe machines have often been made with two parallel glaſs plates, and thoſe of a conſiderable diameter; which plates, turning upon the ſame axis, are rubbed by eight rubbers.—The ſparks obtained from the conductors of thoſe machines are ſtrong, though not very long; yet an electrical battery may be charged by one of thoſe machines very quick, ſince they accumulate an aſtoniſhing quantity of electric fluid. Their principal imperfections are—the great numbe ro frubbers that the operator muſt keep in proper order—the friction ariſing from them, which renders the turning of the machine rather hard—and laſtly, the plates being ſubject to crack very eaſily.

The laſt machine, that I am to deſcribe, is that repreſented in fig. 1 of plate I, which has all the improvements hitherto made, except that it is not capable of admitting different kinds, or more than one Electric, but which, indeed, it ſeems not to ſtand in need of. The electric power of ſuch a machine, I think, is equal to what may be obtained by any other conſtruction; and at the ſame time its ſize, being neither remarkably large, nor at all inconvenient, renders it, I think, the *completeſt machine* hitherto contrived*.

The frame of this machine conſiſts of the bottom board A B C, which, when the machine is to be uſed, is faſtened to the table by two iron cranks, one of which appears in the figure near C. Upon the bottom board are perpendicularly raiſed two ſtrong wooden pillars K L, and A H, which ſupport the cylinder, and the wheel. From one of the braſs caps of the cylinder F F, an axle of ſteel proceeds, which paſſes quite through a hole in the pillar K L, and has on this ſide of the pillar a pulley I, fixed upon its ſquare extremity. Upon the circumference of this pulley there are three or four grooves, in order to ſuit the variable length of the ſtring *a b*, which goes round one of them, and round the groove of the wheel D. The other cap of the cylinder has a ſmall cavity, which fits the conical extremity of a ſtrong ſkrew, that proceeds from the pillar H. The wheel D, which is moved by the handle E, turns round a ſtrong axle, proceeding from almoſt the middle of the pillar K L.

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* Theſe machines are made, and ſold, by Mr. GEORGE ADAMS, in Fleet-ſtreet, London, philoſophical inſtrument-maker to his Majeſty.

The rubber G of this machine is on each end three or four inches ſhorter than the cylinder (*i. e.* the cylinder excluſive of the necks), and it is made to rub about one fifth part of the cylinder's circumference, or rather leſs; it conſiſts of a thin quilted cuſhion of ſilk, ſtuffed with hair, and faſtened by ſilk ſtrings upon a piece of wood, which is properly adapted to the ſurface of the cylinder. And to the lower extremity of the cuſhion, or rather of the piece of wood to which the cuſhion is tied, a piece of leather is faſtened, which is turned over the cuſhion, *i. e.* ſtands between it and the ſurface of the cylinder, and to the extremity of which a piece of ſilk or oiled ſilk is faſtened, which covers almoſt all the upper part of the cylinder. Upon this leather, which reaches from the lower to almoſt the upper extremity of the cuſhion, ſome of the above-deſcribed amalgam is to be worked, ſo as to be forced as much as poſſible into its ſubſtance: if moſaic gold is to be tried; then the leather ſhould be new, and whereon no other amalgam has been put. This rubber is ſupported by two ſprings, ſcrewed to its back, and from which it may be eaſily unſcrewed, when occaſion requires it. The two ſprings proceed from the wooden cap of a ſtrong glaſs pillar *, perpendicular to the bottom board of the machine. This pillar has a ſquare wooden baſis, that ſlides in two grooves in the bottom board A B C, upon which it is faſtened by a ſcrew. In this manner the glaſs pillar may be faſtened at any required diſtance, and in conſequence the rubber may be made to preſs harder or lighter upon the cylinder. The rubber in this manner is perfectly inſulated; and, when inſulation is not required, a chain with a ſmall hook may be hanged to it, ſo as to have a regular communication with the piece of leather, the chain then falling upon the table, renders the rubber uninſulated.

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* This glaſs pillar, as well as the glaſs feet of inſulating ſtools in general, ſhould be covered with varniſh, or rather with ſealing-wax, otherwiſe they inſulate very imperfectly, on account of the moiſture that they attract from the air, eſpecially in damp weather. It muſt be obſerved, that ſealing-wax diſſolved in ſpirits of wine, may be uſed very well for this purpoſe; but to cover a piece of glaſs with ſealing-wax, by rubbing a ſtick of it upon the ſurface of the glaſs when hot, anſwers far the better.

Fig. 2 repreſents the prime Conductor AB belonging to this machine. This is of hollow braſs, and is ſupported by two glaſs pillars varniſhed, that by two braſs ſockets are fixed in the board CC. This Conductor receives the electric fluid through the points of the collector L, which are ſet at about half an inch diſtance from the ſurface of the cylinder of the machine.

If the handle E, fig. 1, of the wheel, be turned (and on account of the rubber it ſhould be turned always in the direction of the letters *a b c*) this machine, ſtanding in the ſituation that is repreſented in the figure, will give poſitive Electricity, *i. e.* the prime Conductor will be electrified poſitively, or overcharged with electric fluid; for by the action of rubbing, the cylinder pumps, as it were, the fluid from the rubber, and every other body properly connected with it, and gives it to the prime Conductor. But if a negative Electricity is required, then the chain muſt be removed from the rubber and hung to the prime Conductor; for in this caſe the Electricity of the prime Conductor will be communicated to the ground, and the rubber remaining inſulated, will appear ſtrongly negative. Another Conductor, equal to the Conductor A B, fig. 2, may be connected with the inſulated rubber, and then the operator may obtain as ſtrong negative Electricity from this, as he can poſitive from the Conductor A B, fig. 2.

CHAP. III.

The particular Deſcription of ſome other neceſſary Parts of the electrical Apparatus.

FIG. 4 repreſents a ſtand ſupporting the electrometers D D C C. B is the baſis of it, made of common wood. A is a pillar of wax, glaſs, or baked wood. To the top of the pillar, if it be of wax or glaſs, a circular piece of wood is fixed; but if the pillar be of baked wood, that may conſtitute the whole. From this circular piece of wood proceed four arms of glaſs, or baked wood, ſuſpending at their ends four electrometers, two of which, D D, are ſilk threads about eight inches long, ſuſpending each a ſmall downy feather at its end. The other two electrometers, C C, are thoſe with very ſmall balls of cork, or of the pith of elder; and they are conſtructed in the following manner:—*a b* is a ſtick of glaſs about ſix inches long, covered with ſealing-wax, and ſhaped at top in a ring: from the lower extremity of this ſtick of glaſs proceed two fine linen threads* *c c*, about five inches long, each ſuſpending a cork, or pith-ball *d*, about one-eighth of an inch in diameter. When this electrometer is not electrified, the threads *c c* hang parallel to each other, and the cork-balls are in contact; but when electrified, they repel one another, as repreſented in the figure. The glaſs ſtick *a b* ſerves for an inſulating handle, by which the electrometer may be ſupported, when it is uſed without the ſtand A B.

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* Theſe threads ſhould be wetted in a weak ſolution of ſalt.

Another ſpecies of the above electrometer is repreſented in fig. 3; which conſiſts of a linen thread, having at each end a ſmall cork-ball. This electrometer is ſuſpended by the middle of the thread on any Conductor proper for the purpoſe, and ſerves to ſhew the kind, and quantity of its Electricity.

Fig. 7 repreſents Mr. HENLY's quadrant electrometer, fixed upon a ſmall ſtand, from which it may be occaſionally ſeparated, and fixed upon the prime Conductor, or in any other place at pleaſure. This electrometer conſiſts of a perpendicular ſtem, formed at the top like a ball, and furniſhed at its lower end with a braſs ferrule, by which it may be fixed in one of the holes of the prime Conductor, or in its proper ſtand, as occaſion requires. To the upper part of the ſtem, or pillar, a graduated ivory ſemicircle is fixed, about the middle of which is a braſs arm, which contains a pin, or the ſmall axis of the index. The index conſiſts of a very ſlender ſtick, which reaches from the center of the graduated ſemicircle to the braſs ferrule, and at its lower extremity is faſtened a ſmall cork-ball, nicely turned in a lathe.

The propereſt wood, for the purpoſe of making the pillar and index of this electrometer, is box, and this pillar and index ſhould be well rounded, and made as ſmooth as poſſible. When this electrometer is not electrified, the index hangs parallel to the pillar, as in fig. 7; but when it is electrified, the index recedes more or leſs, according to the quantity of Electricity, from the ſtem; as repreſented on the prime Conductor E, fig. 2.

The main of Mr. LANE's diſcharging Electrometer, conſiſts in a braſs ball about one inch and a half in diameter, ſcrewed to a braſs graduated rod, and adapted to a proper frame, ſo that it may be ſet at any required diſtance from the prime Conductor, or the knob of an electric jar. The principal uſe of this electrometer is to let a jar diſcharge by itſelf through any proper circuit, without uſing any diſcharging rod, or removing any part of the apparatus; and to give ſhocks nearly of the ſame ſtrength. Suppoſe, for inſtance, that the above-mentioned braſs ball be ſet at half an inch diſtance from the prime Conductor, and that a coated jar be ſituated ſo as to touch the prime Conductor with its knob, and to have its outſide coating communicating with the above-mentioned braſs ball. Now it is evident that the circuit, from the outſide to the inſide of the jar, is interrupted only between the prime Conductor and the braſs ball, which lie half an inch aſunder; therefore, when the jar is charging, and the charge is become ſo high as to ſtrike through half an inch of air, the jar will diſcharge itſelf, and, by keeping the braſs ball at the ſame diſtance from the prime Conductor, and charging the jar ſucceſſively, the ſhocks will be of the ſame ſtrength.

This electrometer is ſubject to an inconvenience; which is, that the ſurface of the braſs ball is ſometimes deprived of its ſmoothneſs by the force of the exploſion; in which caſe it is neceſſary to poliſh it again, otherwiſe the inſtrument is uſeleſs. An electrometer of this kind, though not exactly like the original one, is now commonly uſed by the practitioners of medical electricity, and is delineated in fig. 6. of Plate II. It conſiſts of a glaſs arm D, which proceeds from the wire of the jar F, and to the extremity E of which a ſpring ſocket is cemented, through which a wire paſſes, which is furniſhed with a knob B, towards the knob A of the jar, and of an open ring C at its other extremity. Now, as this wire may be ſlided backwards and forwards, the knob B may be put at any required diſtance from the knob A, as far as the conſtruction of the inſtrument will allow. The wire B C is generally marked with diviſions, which ſhew the diſtance of the two knobs, when the wire is ſo ſituated, as that the required diviſion coincides with the edge of the ſpring ſocket, as for inſtance, one tenth, or one quarter of an inch, &c. When the jar F is ſet againſt the prime conductor G, as repreſented in the figure, ſuppoſe that the ball B is ſet at the diſtance of $\frac{1}{16}$ of an inch from the ball A, and that a wire be fixed from the electrometer's ring to the outſide coating of the jar, as ſhewn by the dotted line CK; then, when the machine is put in motion, the diſcharge of the jar, as ſoon as this becomes ſufficiently charged, will be made between the knobs A B, and through the wire C K; and it is evident that theſe diſcharges will be of the ſame ſtrength, as long as the diſtance between A B remains the ſame.

Fig. 5 of Plate I. repreſents Mr. HENLY's univerſal diſcharger, which is of a very extenſive uſe, and is compoſed of the following parts:—A is a flat board fifteen inches long, four inches broad, and one thick, or thereabouts, which forms the baſis of the inſtrument. B B are two glaſs pillars, cemented in two holes upon the board A, and furniſhed at their top with braſs caps, each of which has a turning joint, and ſupports a ſpring tube, through which the wire D C ſlides: each of theſe caps is compoſed of three pieces of braſs, connected ſo, that the wire D C, beſides its ſliding through the ſocket, has two other motions, *viz.* an horizontal and a vertical one. Each of the wires D C, D C is furniſhed with an open ring at one end, and at the other end has a braſs ball D, which, by a ſhort ſpring ſocket, is ſlipt upon its pointed extremity, and may be removed from it at pleaſure. E is a ſtrong circular piece of wood, five inches in diameter, having, on its ſurface, a ſlip of ivory inlaid, and furniſhed with a ſtrong cylindrical foot, which fits the cavity of the ſocket F, which is faſtened in the middle of the bottom board, and has a ſcrew G, which ſerves to faſten the foot of the circular board E at any required height. H is a ſmall preſs belonging to this inſtrument; it conſiſts of two oblong pieces of board, which may be preſſed againſt each other by means of two ſcrews *a a*: the lower of theſe boards has a cylindrical foot equal to the foot of the circular board E. When this preſs is to be uſed, it is fixed into the ſocket F, in the place of the circular board E, which muſt, in that caſe, be removed.

Fig. 11 is an electric jar coated with tin-foil on the inſide and outſide, within

three

three inches of the top of the cylindrical part of the glaſs, having a wire with a round braſs knob A at its extremity. This wire paſſes through the cork * D, that ſtops the mouth of the jar, and at its lower end, is bended ſo as to touch the inſide coating in ſeveral places.

Fig. 10 repreſents a battery compoſed of ſixteen jars, coated in the inſide and outſide with tin-foil, which all together contain about twelve feet of coated glaſs. About the middle of each of theſe jars is a cork that ſuſtains a wire, which at the top is faſtened round, or ſoldered to the wire E, knobbed at each end, which connects the inſide coatings of four jars; and by the wires F F F the inſide coatings of all the ſixteen jars are connected together. Each of the wires F has a ring at one end, through which one of the wires E paſſes, and at the other end has a braſs knob. If the whole force of the battery is not required, one, two, or three rows of jars may be uſed

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* When corks are uſed to ſtop electric jars, they ſhould be made very dry, and dipped in melted bees-wax, or varniſhed.

at pleaſure; for as each of the wires F F F is moveable round the wire E, which paſſes through its ring, and reſts upon the next wire E, it may be eaſily removed from that, and turned upon the contrary wire E; and thus the communication between one row of jars and another may be diſcontinued at pleaſure. See the figure.

The ſquare box that contains theſe jars is of wood lined at the bottom with ſheet-lead or tin, and has two handles on two oppoſite ſides, by which it may be eaſily removed. In one ſide of the box is a hole, through which an iron hook B paſſes, which communicates with the metallic lining of the box, and conſequently with the outſide coating of all the jars. To this hook is faſtened a wire, the other end of which is connected with the diſcharging-rod.

The diſcharging-rod conſiſts of a glaſs handle A, and two curved wires B B, which move by a joint C, fixed to the braſs cap of the glaſs handle A. The wires B B are pointed, and the points enter the knobs

D D, to which they are ſcrewed, and may be unſcrewed from them at pleaſure. By this conſtruction we have the opportunity of uſing the balls or the points, as occaſion requires; and as the wires are moveable by the joint C, they may be adapted to ſmaller or larger jars at pleaſure.

The battery, repreſented in the plate, is a ſmall one in compariſon to thoſe now frequently uſed, and much too weak for the purpoſe of ſome experiments, hereafter to be deſcribed. But I thought it ſufficient to give an idea of its conſtruction; and, when a large battery is to be conſtructed, I would recommend rather to make two, three, or more ſmall ones, as repreſented in the plate, than a ſingle large battery, which is heavy, and, on ſeveral accounts, inconvenient. The force of ſeveral ſmall batteries may be eaſily united by a wire or a chain, and thus they may be made to act like a large one.

F in fig. 2. is a circular braſs plate hung on the prime Conductor by a chain, and reſting in an horizontal poſition. Underneath this, there is another plate P parallel, and equal to the former (but it would be better if it was a little larger), which is ſupported by a ſtand H of braſs, having alſo a ſocket to receive the foot of the plate, and a ſcrew G to fix it at different diſtances.

D in fig. 2. is a fly made of ſmall braſs wires, fixed in a cap of braſs alſo; which is to be put upon the pointed wire K, that is ſcrewed to the prime conductor, upon which it muſt ſtand in equilibrio, like the needle of a compaſs. The other ends *a*, *b*, *c*, *d* of the wires are pointed, and bent all one way.

N. B. Whenever hereafter I mention the prime Conductor, I mean the prime Conductor naked, that is, without the parallel braſs plates F P, without the fly D and its ſupporting pin K, without the electrometers E, and even without the knobbed rod I B, which is ſcrewed to it occaſionally; except the contrary is expreſſed.

It is highly requiſite for an Electrician to have by him ſeveral inſulating ſtools, or ſtands, they being very neceſſary for ſeveral experiments. The beſt materials to conſtruct theſe are glaſs covered with ſealing-wax, and baked wood*. A large ſtool, proper to inſulate a chair upon, or two or three perſons ſtanding, may be made with a ſtrong board, about two feet and a half ſquare, and may be ſupported by four feet of glaſs, about eight inches long. But ſmall ſtands are better made with one foot or pillar, and all of baked wood or glaſs, without any conducting ſubſtance in their conſtruction. Drinking-glaſſes, either varniſhed, or in part covered with ſealing-wax, anſwer this purpoſe very well.

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* The wood ſhould be baked very well, even till it becomes quite brown, it then being in the beſt ſtate for inſulation; and to make it ſtill better, *i. e.* to defend it from moiſture, it may be ſlightly varniſhed as ſoon as it comes out of the oven, or elſe boiled in linſeed-oil; but in this caſe, after boiling, it ſhould be made hot again, and then it is fit for uſe.

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CHAP. IV.

Practical Rules concerning the Uſe of the electrical Apparatus, and the performing of Experiments.

IT often happens that young Electricians are at a loſs to aſſign the reaſon, why ſome experiments do not ſucceed with them as deſcribed in the Treatiſes on Electricity. Sometimes they are in poſſeſſion of very good inſtruments, but, by reaſon of ſome circumſtance or other unattended to, they are quite uſeleſs in their hands. This indeed can be remedied by nothing but practice, and it is by long uſe, that the Electrician, as well as the Practitioner in any art or ſcience, becomes ſo good an Operator, as to uſe his inſtruments to the beſt advantage. A few rules are however very neceſſary, to guide him in his operations; and although theſe alone are inſufficient to make a perſon a complete practical Electrician, yet, when accompanied with the actual management of the apparatus, they facilitate the uſe of it, and render the performance of the experiments more accurate and expeditious.

The firſt thing that the young Electrician ſhould obſerve, is, the preſervation, and care, of his inſtruments. The electrical machine, the coated jars, and in ſhort every part of the electrical apparatus, ſhould be kept clean, and as free as poſſible from duſt, and moiſture.

When the weather is clear, and the air dry, eſpecially in clear and froſty weather, the electrical machine will always work well. But when the weather is very hot, the electrical machine is not ſo powerful: nor in damp weather, except it be brought into a warm room; and the cylinder, the ſtands, the jars, &c. be made thoroughly dry.

Before the machine be uſed, the cylinder ſhould be firſt wiped very clean with a ſoft linen cloth, that is dry, clean, and warm; and afterwards with a clean hot flannel, or an old ſilk handkerchief; this done, if the winch be turned, when the prime Conductor, and other inſtruments, are removed from the electrical machine, and the knuckle be held at a little diſtance from the ſurface of the cylinder, it will be ſoon perceived that the electric fluid comes like a wind from the cylinder to the knuckle, and, if the motion be a little continued, ſparks, and crackling will ſoon follow. This indicates that the machine is in good order, and the Electrician may proceed to perform his experiments. But if, when the winch is turned for ſome time, no wind is felt upon the knuckle, then the fault is, very likely, in the rubber; and to remedy that, uſe the following directions:—By unſcrewing the ſcrews on the back of the rubber, remove it from its glaſs pillar, and keep it a little near the fire, ſo that its ſilk part may be dried; take now a dry piece of mutton-ſuet, or a little tallow from a candle, and juſt paſs it over the leather of the rubber, then ſpread a ſmall quantity of the above-deſcribed amalgam over it, and force it as much as poſſible into the leather. This done, replace the rubber upon the glaſs pillar; let the glaſs cylinder be wiped once more, and then the machine is fit for uſe.

Sometimes the machine will not work well, becauſe the rubber is not ſufficiently ſupplied with electric fluid; which happens when the table upon which the machine ſtands, and to which the chain of the rubber is connected, is very dry, and conſequently in a bad conducting ſtate. Even the floor and the walls of the room are, in very dry weather, bad Conductors, and they cannot ſupply the rubber ſufficiently. In this caſe, the beſt expedient is, to connect the chain of the rubber, by means of a long wire, with ſome moiſt ground, a piece of water, or with the iron-work of the water pump; by which means the rubber will be ſupplied with as much electric fluid as is required.

It muſt be alſo remarked, that when the cylinder is very hot, as above 110°, it will not act well.

When a ſufficient quantity of amalgam has been accumulated upon the leather of the rubber, and the machine does not work very well, then, inſtead of putting more amalgam, it will be ſufficient to take the rubber off, and to ſcrape a little, that which is already upon the leather.

It will be often obſerved, that the cylinder, after being uſed ſome time, contracts ſome black ſpots, occaſioned by the amalgam, or ſome foulneſs of the rubber, which grow continually larger, and greatly obſtruct its electric power. Theſe ſpots muſt be carefully taken off, and the cylinder muſt be frequently wiped, in order to prevent its contracting them.

In charging electric jars in general, it muſt be obſerved, that not every machine will charge them equally high. That machine, whoſe electric power is the ſtrongeſt, will always charge the jars higheſt. If the coated jars, before they are uſed, be made a little warm, they will receive, and hold the charge the better.

If ſeveral jars are connected together, among which there is one, that is apt to diſcharge itſelf very ſoon, then the other jars will alſo ſoon be diſcharged with that;

although they may be capable of holding a very great charge by themſelves. When electric jars are to be diſcharged, the Electrician muſt be cautious leſt, by ſome circumſtance not adverted to, the ſhock ſhould paſs through any part of his body; for an unexpected ſhock, though not very ſtrong, may occaſion ſeveral diſagreeable accidents. In making the diſcharge, care muſt be taken that the diſcharging-rod be not placed on the thinneſt part of the glaſs, for that may cauſe the burſting of the jar.

When large batteries are diſcharged, jars will be often found broken in it, which burſt at the time of the diſcharge. To remedy this inconvenience, Mr. NAIRNE ſays he has found a very effectual method; which is, never to diſcharge the battery through a good Conductor, except the circuit be at leaſt five feet long. Mr. NAIRNE ſays, that ever ſince he made uſe of this precaution, he has diſcharged a very large battery near a hundred times, without ever breaking a ſingle jar, whereas before he was continually breaking them. But here it muſt be con-

ſidered,

ſidered, that the length of the circuit weakens the force of the ſhock proportionably; the higheſt degree of which is in many experiments required.

When a coated phial is cracked, either by a ſpontaneous diſcharge, or by any other accident, I remove the outſide coating from the fractured part, and then make it moderately hot by holding it to the flame of a candle, and whilſt it remains hot I apply burning ſealing-wax to the part, ſo as to cover the fracture entirely; taking care that the thickneſs of the wax is rather more than the thickneſs of the glaſs. Laſtly, I cover all the ſealing-wax, and alſo part of the ſurface of the glaſs beyond it, with a compoſition made with four parts of bees-wax, one of reſin, one of turpentine, and a very little oil of olives; which compoſition I ſpread upon a piece of oiled ſilk, and apply it in the manner of a plaiſter. With this method I have repaired ſeveral broken phials ſo effectually, that, after being frequently charged, they were at laſt broken by a ſpontaneous diſcharge, but in a different part of the glaſs *.

It is adviſeable, when a jar, and eſpecially a battery, has been diſcharged, not to touch its wires with the hand, before the diſcharging-rod be applied to its ſides a ſecond, and even a third time; as there generally remains a reſiduum of the charge †, which is ſometimes very conſiderable.

When any experiment is to be performed, which requires but a ſmall part of the apparatus, the remaining part of it ſhould be placed at a diſtance from the machine, the

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* Here it is proper to remark, that when jars, or glaſs in general, that is coated for the purpoſe of charging and diſcharging, is in any manner covered with cement or ſealing-wax, it breaks more eaſily by a ſpontaneous diſcharge; and it is very remarkable, that the fracture generally lies on the limits of the cement.

† This reſiduum is in great meaſure occaſioned by the Electricity, that, when the jar is charging, ſpreads itſelf over the uncoated part of the glaſs near the coating, which will not be diſcharged at firſt, but gradually returns to the coating after the firſt diſcharge.

prime Conductor, and even from the table, if that is not very large. Candles, particularly, ſhould be placed at a conſiderable diſtance from the prime Conductor, for the effluvia of their flames carry off much of the electric fluid.

Laſtly, the young Electrician ſhould be cautioned not to depend on firſt appearances in Electricity. A new phenomenon may juſtly excite his curioſity: it is laudable to remark it, and to purſue the hint; but at the ſame time even the doubtful aſſertion of a new fact ſhould never be made, till after a number of ſimilar and concurring experiments. Electricity is a ſcience that often deceives the ſenſes, and the moſt experienced Electrician frequently finds himſelf miſtaken in things, which perhaps he may have before conſidered as the moſt certain.

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CHAP. V.

Experiments concerning electric Attraction, and Repulſion.

EXPERIMENT I.

The electrified Cork-ball Electrometer.

WHEN the electrical machine is put in order, and the prime Conductor it ſet ſo, that the points of the collector are about half an inch from the ſurface of the cylinder, fix at the end of the prime Conductor the knobbed rod I B fig. 2. and hang on it the electrometer with the cork-balls fig. 3. The balls will now touch one another, the threads hanging perpendicularly, and parallel to each other. But if the cylinder of the machine be whirled by turning the winch E, then the cork-balls will repel one another, and more, or leſs, according as the Electricity is more or leſs powerful.

In this experiment, the glaſs cylinder extracting the electric fluid from the rubber, throws it upon the pointed wires of the collector, and in conſequence upon the prime Conductor, and the electrometer; which are all connected together: and as bodies overcharged with electric fluid will always repel each other, ſo the cork-balls muſt repel each other.

If the electrometer be hung to a prime Conductor negatively electrified, *i. e.* connected with the inſulated rubber of the machine, the cork-balls will alſo repel each other; for bodies, undercharged, will repel each other, as well as bodies overcharged with electric fluid.

If, in this ſtate of repulſion, the prime Conductor is touched with ſome conducting ſubſtance not inſulated, the cork-balls will immediately come together; for the electric fluid ſuperinduced upon the prime Conductor, and the electrometer communicating with it, will be carried away to the ground by that conducting body; ſo that in this caſe the prime Conductor can never be overcharged:

charged: nor can it be undercharged, if connected with the rubber; for its deficiency of fluid is ſupplied through that conducting body, with which it has been touched. But if, inſtead of the conducting ſubſtance, the prime Conductor is touched with an electric, as for inſtance a ſtick of ſealing-wax, a piece of glaſs, &c. then the cork-balls will continue to repel each other; becauſe the electric fluid cannot be conducted through that electric: hence we have an eaſy method of determining what bodies are Conductors, and what electrics *.

This electrical repulſion is alſo ſhewn by the quadrant electrometer, with a large downy feather, or the like; for if theſe be connected with the prime Conductor, and the winch be turned, the electrometer will raiſe its index, and the feather, by the divergency of its down, will appear ſwelled in a beautiful manner.

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* This method in groſs will do very well; but when the conducting power of fluids or ſome other bodies, and the degree of that power, is to be aſcertained, then recourſe muſt be had to other means more nice, and accurate.

EXPERIMENT II.

Attraction and Repulſion of light Bodies.

Connect with the prime Conductor the two parallel braſs plates F, P, as repreſented in fig. 2. at about three inches diſtance from one another, and upon the lower plate put any kind of light bodies, as bran, bits of paper, bits of leaf-gold, &c. then work the machine, and the light bodies will ſoon move between the two plates, leaping alternately from one to the other with great velocity. If, inſtead of bran, or irregular pieces of other matter, ſmall figures of men or other things cut in paper, and painted, be put upon the plate, they will generally move in an erect poſition, but will ſometimes leap one upon another, or exhibit different poſtures, ſo as to afford a pleaſing ſpectacle to an obſerving company.

In this experiment, both the attraction, and repulſion of Electricity are obſerved at the ſame time: for when the upper plate

F, which communicates with the prime Conductor, is electrified, the ſmall bodies placed upon the lower plate, together with that plate, by being within the ſphere of action of the electrified upper plate, become actually poſſeſſed of a contrary Electricity, leaving their proper quantity of fluid in the lower plate, or the other conducting bodies, that communicate with it. But bodies differently electrified attract each other; therefore the plate F, attracts thoſe light bodies. Now, as ſoon as theſe bodies touch the plate F, they become inſtantly poſſeſſed of the ſame Electricity with the plate, and will therefore be immediately repelled to the lower plate, which is actually electrified with the contrary Electricity, and by touching the light bodies, aſſiſts in repelling them again to the upper plate; and thus the plates continue to act upon the light bodies alternately.

That the light bodies cannot be attracted by the upper plate, except they become firſt poſſeſſed of a contrary Electricity, may be obſerved as follows:—Put the ſaid light bodies upon a clean, and dry pane of glaſs;

then take off the braſs plate P, with its ſtand G, and in its ſtead put the pane of glaſs, holding it by one corner; this done, let the wheel of the machine be turned, and you will ſee that the light bodies are not attracted by the braſs plate F; for in this caſe they have no opportunity of parting with their proper quantity of fluid, and conſequently cannot acquire the contrary electricity. But if to the under ſide of the pane of glaſs, on which the light bodies are placed, a finger or any other conductor be preſented, the light bodies will be inſtantly attracted by the plate F, and will leap between the glaſs and plate, in the ſame manner as between the two plates; for theſe bodies now depoſit their fluid upon the upper ſurface of the glaſs plate, whilſt the under ſurface depoſits its fluid upon the finger, or other conductor, that has been brought near it*. If this experiment be continued, the glaſs will ſoon be charged †.

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* If the above experiment be made with a prime Conductor negatively electrified, the effect will be the ſame, only the Electricities of the plates are reverſed; *i. e.* the upper plate is electrified negatively, and the under plate, by being in the atmoſphere of the upper one, is poſitively electrified.

EXPERIMENT III.

The Flying-feather, or Shuttle-cock.

The phenomena of electric attraction and repulſion may be repreſented alſo with a glaſs tube, or a charged bottle, and ſome of them in a manner more ſatisfactory than with the machine.

Take a glaſs tube (whether ſmooth, or rough, is not material), and after having rubbed it, let a ſmall light feather be let out of your fingers at the diſtance of about eight or nine inches from it. This feather will be immediately attracted by the tube, and will ſtick very cloſe to its ſurface for about two or three ſeconds, and ſometimes longer; after which time it will be repelled, and if the tube be kept under it, the feather will continue floating in the air at a conſiderable diſtance from the tube, without coming near it again, except it firſt touches ſome conducting ſubſtance; and if you manage the tube dexterouſly, you may drive the feather through the air of a room at your pleaſure.

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† Electric attraction and repulſion takes place alſo within a vacuum, made by means of common air-pumps.

The reaſon of this experiment is obvious; for when the feather is electrified, it cannot approach the tube again, except it firſt touches ſome conducting body, becauſe it cannot part with its Electricity when floating in the air, and therefore cannot acquire a contrary Electricity: conſequently it muſt remain in a ſtate incapable of being again attracted by the excited tube.

If it be aſked, Why, when the feather is at firſt attracted by the tube, it ſticks for ſo conſiderable a time to its ſurface before it is repelled? the anſwer is, That the feather being an electric, requireth ſome time before it acquires any conſiderable quantity of Electricity.

There is a remarkable circumſtance attending this experiment, which is, that if the feather be kept at a diſtance from the tube by the force of electric repulſion, it always preſents the ſame part towards the tube:—You may move the excited tube about the feather very ſwiftly, and yet the ſame ſide of the feather will always be preſented to the tube. The reaſon of this phenomenon is, that the equilibrium of the electric fluid in the parts of the feather, being once diſturbed, cannot eaſily be reſtored; becauſe the feather is an electric, or at leaſt a very bad Conductor. When the feather has acquired a quantity of Electricity from the tube, it is plain, that by the action of the excited tube, that ſuperinduced electricity will be in the greateſt part forced on that ſide of the feather which happens to be at firſt the fartheſt from the tube; hence that part will always afterward be repelled the fartheſt.

This experiment may be agreeably varied in the following manner:—A perſon may hold in his hand an excited tube of ſmooth glaſs, and another perſon may hold an excited rough glaſs tube, a ſtick of ſealing-wax, or in ſhort another electric negatively electrified, at about one foot and a half diſtance from the ſmooth glaſs tube: a feather now may be let go between theſe two differently-excited electrics, and it will leap alternately from one electric to the other; and the two perſons will ſeem to drive a ſhuttle-cock from one to the other, by the force of Electricity.

EXPERIMENT IV.

The ſmall inſulated Body.

Tie a ſmall body, as for inſtance a light piece of cork, to a ſilk thread about eight inches long, and holding the thread by its end, let the ſmall body hang at the diſtance of about eight inches from the ſide of the prime Conductor electrified. This ſmall body, if the electrification of the Conductor is not ſtrong, will not be attracted; for, being inſulated, it cannot, by depoſiting its fluid upon, or receiving it from another body (when the prime Conductor is electrified negatively), become contrarily electrified. But if a finger or any conducting ſubſtance be preſented to the ſide of the ſmall body which is fartheſt from the prime Conductor, then the ſmall body will immediately move toward the prime Conductor; for it has depoſited its own fluid upon, or acquired ſome (in caſe the Conductor is negatively electrified) from the body preſented to it; and when this body has touched the prime Conductor, it will be inſtantly repelled from it, on account of the repulſion exiſting between bodies poſſeſſed of the ſame kind of Electricity.

Indeed, if this inſulated body be very near to the prime Conductor, or the prime Conductor ſtrongly electrified, then the ſmall body will be attracted without preſenting to it any conducting ſubſtance; but in this caſe its natural quantity of electric fluid will be either repelled into the contiguous air, or crouded on the part of the body which is fartheſt from the prime Conductor, if the Conductor is electrified *poſitively*; but if it is electrified *negatively*, then the additional quantity of fluid, neceſſary to render the ſmall body overcharged, will be acquired from the air, or the natural fluid belonging to that body will be all crouded on that ſide of it, which is neareſt to the prime Conductor.

If this ſmall body, inſtead of the ſilk, be ſuſpended by a linen thread, it will be attracted at a much greater diſtance, than in the other caſe; for now the electric fluid will eaſily be conducted by the thread, paſſing upwards, or downwards according as the prime Conductor is electrified, *viz.* negatively, or poſitively.

EXPERIMENT V.

The electric Well.

Place upon an electric ſtool a metal quart mug, or ſome other conducting body nearly of the ſame form and dimenſion; then tie a ſhort cork-ball electrometer, of the kind repreſented fig. 3,* at the end of a ſilk thread proceeding from the ceiling of the room, or from any other proper ſupport, ſo that the electrometer may be ſuſpended within the mug, and no part of it may be above the mouth; this done, electrify the mug, by giving it a ſpark with an excited electric or otherwiſe, and you will ſee that the electrometer, whilſt it remains in that inſulated ſituation, even if it be made to touch the ſides of the mug, is not attracted by it, nor does it acquire any Electricity; but, if whilſt it ſtands ſuſpended within the mug, a Conductor, ſtanding out of the mug, be made to communicate with, or only preſented to it, then the electrometer acquires an Electricity contrary to that of the mug, and a quantity of it, which is proportionable to the body with which it has been made to communicate; and it is then immediately attracted by the mug.

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* Inſtead of the electrometer, there may be uſed any other kind of ſmall conducting body; but that ſeems beſt adapted to ſuch experiments.

The reaſon why in this experiment the electrometer contracts no Electricity whilſt ſuſpended intirely within the cavity of the mug, is, becauſe the Electricity of the mug acts upon the electrometer on all ſides, and this has no opportunity of parting with its fluid, when the mug is electrified poſitively;

nor of receiving any, when the mug is electrified negatively. But, as ſoon as any Conductor communicates with it, the electrometer becomes immediately poſſeſſed of the Electricity contrary to that of the mug; for if the mug be electrified poſitively, the fluid belonging to the electrometer will be repelled to that body, which communicates with it; and which, being out of the mug, cannot be affected by its Electricity; and if the mug is electrified negatively, it will attract the fluid of the electrometer, which actually receives an additional quantity of it from that conducting body, with which it communicates. The electrometer therefore, becoming always poſſeſſed of a contrary Electricity, muſt neceſſarily be attracted.

If, by raiſing the ſilk thread a little, part of the electrometer, *i. e.* of its linen threads, are lifted juſt above the mouth of the mug, the balls will be immediately attracted; for then, by the action of the Electricity of the mug, it will acquire a contrary Electricity by giving to, or receiving the electric fluid from, the air above the cavity of the mug.

It

It has been ſuppoſed by ſome, that the electrometer in the above experiment (or any other ſmall inſulated body), hanging in the cavity of an electrified veſſel, or the like, is not attracted by the ſides of the veſſel, becauſe the attraction of Electricity, being as the ſquares of the diſtances inverſely, cannot affect the electrometer one way more than another; it being demonſtrable, that, if to every point of a ſpherical concave ſurface, equal centripetal forces are directed, decreaſing as the ſquares of the diſtances from thoſe points, a ſmall body ſituated any where within that ſurface, would remain there, without being attracted one way more than another *.

But to this it may be replied, that the demonſtration of the above-mentioned propoſition, if it is applicable to ſpherical, or cylindrical concave ſurfaces, cannot, however, be applied to every kind of irregular cavities, with which (if they exceed not a certain ſize) the above experiment ſucceeds as well, as with the cylindrical cavity of the mug.

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* NEWTON's Principia book I. prop. LXX.

In ſhort, in this experiment, when the mug is electrified poſitively, it is ſuppoſed, I. That the ſuperinduced fluid, taking place upon the external ſurface, occaſions the contiguous air to depoſit its fluid upon a ſubſequent quantity of air, and this overcharged air occaſions a contiguous circle, or quantity of air, to depoſit its fluid upon its ſubſequent or next adjacent circle, and ſo on. II. That none of the ſuperinduced fluid can exiſt upon the internal ſurface of the mug, and therefore, inſulated bodies intirely ſuſpended therein, can acquire no electricity, becauſe the internal air has no opportunity of parting with its own fluid, except a ſmall quantity about the mouth of the mug, where, accordingly, a little Electricity is obſervable. When the mug is electrified negatively, then it is ſuppoſed I. That the deficiency of fluid in the mug is only on its external ſurface; for the air, contiguous to this ſurface, by acquiring an additional quantity of electric fluid from the next ſtratum of air, may become electrified poſitively. II. That the internal ſurface of the mug is not undercharged, becauſe its contiguous air, being ſurrounded by the mug, cannot become overcharged, by acquiring an additional quantity of fluid, except a ſmall quantity towards the mouth of the mug, where, accordingly, a little Electricity is obſervable.

EXPERIMENT VI.

To diſtinguiſh the Quality of Electricity in electrified Bodies.

Before we proceed further, it is neceſſary, that we ſhould deſcribe ſome practical method of diſtinguiſhing the quality of the Electricity in an electrified body, which is abſolutely neceſſary for the right performance of the enſuing experiments. To do this, different methods may be followed, which however are all founded, either upon the electric attraction, and repulſion, or upon the different appearances of the electric light. To find out the quality of Electricity by the different appearances of its light, is a very convenient, and ſure method; but the phenomena of attraction and repulſion, afford one much more general, and eaſy; for ſometimes the quantity of Electricity to be obſerved is ſo very

ſmall,

ſmall, that it will give no light, though it may be ſtill capable of attracting or repelling.

The general method to prove whether the Electricity of a body, electrified either by excitation, or communication, is negative, or poſitive, is, to bring it pretty near to an electrified electrometer D or C fig. 4, and obſerve whether the body attracts or repels it; for if the electrometer is electrified poſitively, and the electrified body repels it, then you may conclude that the body is alſo electrified poſitively; becauſe bodies, poſſeſſed of the ſame kind of Electricity, repel each other; but if the body preſented attracts the Electrometer, then it muſt be electrified negatively, becauſe there is no electric attraction between bodies, unleſs they are differently electrified; and as the electrometer is known to be electrified poſitively, the body is conſequently electrified negatively.

This may be alſo done by electrifying the electrometer negatively; but then the effects are juſt the contrary, *i. e.* the electrified

fied body, if negative, will repel the electrometer, and if poſitive, will attract it.

In this experiment, however, it muſt be obſerved, that, if the Electricity of the electrified body is much ſtronger, than that of the electrometer, or the Electricity of the latter ſtronger, than that of the former, and the electrified body be brought very near the electrometer, then they will attract one another, notwithſtanding they are poſſeſſed of the ſame kind of Electricity. Suppoſe, for inſtance, that one of the electrometers C is poſitively electrified, ſo that its cork-balls may diverge about half an inch, and a glaſs tube ſtrongly excited be brought near it; when this tube is a foot diſtant, or more, the electrometer will be a little repelled by it; but if the tube be brought nearer, the cork-balls, that before diverged half an inch, will now converge till they are in contact, and appear, as they actually are, unelectrified; becauſe the action of the excited tube has repelled their ſuperfluous fluid through the threads up to the remoteſt part of the electrometer. If the tube be preſented ſtill nearer, the balls will then be attracted by it, becauſe the ſtronger Electricity of the tube repels not only their ſuperinduced, but alſo their natural quantity of fluid up the threads, &c. and therefore the balls, becoming negatively electrified, muſt neceſſarily be attracted by the tube.

Upon this principle an electrometer may be electrified negatively by means of an electric poſitively excited; or, on the contrary, it may be electrified poſitively by an electric poſſeſſed of the negative Electricity. Take for inſtance a glaſs tube excited poſitively, and bring it within ſix or ſeven inches under the balls of one of the abovesaid electrometers; in which caſe the balls of the electrometer will diverge, becauſe their natural quantity of electric fluid has been driven from them to the upper part of the threads by the action of the tube poſitively excited; ſo that the balls in reality diverge with negative Electricity. Now, in this ſtate touch the upper part of the threads of the electrometer with your finger, which will take off ſome of the electric fluid natural to the electrometer;

after which remove the finger, and immediately after remove the glaſs tube, and the electrometer will remain electrified negatively, becauſe the excited glaſs tube did not impart any electric fluid to the electrometer, but only diſturbed the equilibrium of the natural quantity of electric fluid, which belonged to the electrometer, and part of which eſcaped through the finger that touched the electrometer, and which did conſequently remain in a negative ſtate.—After the like manner the electrometer may be electrified poſitively, by means of a body poſſeſſed of negative Electricity.

But ſhould a more preciſe method than the above be required, to determine the quality of the Electricity of an electrified body, the following may be uſed:—Firſt, electrify one of the electrometers C, placed upon the ſtand fig. 4, either poſitively, or negatively, at pleaſure: touch it, for inſtance, with an excited glaſs tube, ſo that its balls may repel, and ſtand about two inches diſtant from one another; then touch the other electrometer C with the electrified body, that you deſire to examine, ſo that it may be poſſeſſed of the ſame degree of Electricity: Laſtly, take either of the two electrometers by the top of the glaſs handle *a*, diſengage it from the arm of the ſtand, and bring it near the other electrometer; if then, the balls of one electrometer repel thoſe of the other, you may conclude that they are poſſeſſed of the ſame kind of Electricity; but if they attract each other, you may conclude that they were electrified with contrary Electricities; and as you know the Electricity of that electrometer, which was firſt electrified, you will alſo know the Electricity of the other electrometer, *i. e.* of the electrified body, with which it was touched.

The above experiment may be alſo made with the ſingle-thread electrometers; for if they are brought near to one another, when their feathers are electrified, they will, if poſſeſſed of the ſame Electricity, repel, or if poſſeſſed of contrary Electricities, attract each other.

EXPE-

EXPERIMENT VII.

The inſulated metallic Rod.

Inſulate in an horizontal poſition a metallic rod about two feet long, having blunt ends, and to one of its ends ſuſpend an electrometer, like that repreſented fig. 3; then bring within three or four inches diſtance of its other end an excited glaſs tube. On the approach of the tube, the balls of the electrometer will open, and if you preſent towards them a body poſitively electrified, you will perceive, that they diverge with poſitive Electricity. If the tube is removed, the balls come together again, and no Electricity remains in them, or in the metallic rod. But if while the tube is near one end of the rod, and the balls diverge with poſitive Electricity, the other end of the rod, *viz.* that from which the electrometer hangs, be touched with ſome Conductor, the cork-balls will come immediately together, and they will remain ſo when the Conductor has been removed;—remove now the excited glaſs tube, and the balls will immediately diverge with negative Electricity; which ſhows that the rod remains undercharged, *i. e.* electrified negatively.

The reaſon of this experiment is, that the repelling power of the excited tube, driving the fluid of one end of the rod to its other end, *i. e.* to that, with which the electrometer is connected, renders this end electrified poſitively; but in fact the tube communicates no Electricity to the rod, it only diſturbs the equable diffuſion of its fluid: in conſequence of this, the electrometer, hanging to the overcharged end of the rod, muſt neceſſarily appear to be electrified poſitively; but when the tube is removed, then the electrometer appears again unelectrified: for the fluid, which had by the action of the tube been driven to one end of the rod, now retires to its former ſituation, and leaves the rod with the electrometer unelectrified.

In the ſecond caſe, when the balls of the electrometer diverge with poſitive Electricity, if that end of the rod is touched with ſome conductor, all its ſuperfluous fluid, which is no other, than that belonging to the oppoſite end of the rod, will be communicated to that body, with which the rod is touched, and therefore the electrometer remains unelectrified: but now in fact the rod has loſt ſome of its natural quantity of fluid; for if the end of it, that is fartheſt from the excited tube, remains in its natural ſtate, the other end is undercharged; conſequently, when the tube is removed, the ſmall quantity of fluid that remains in the rod will diffuſe itſelf uniformly through it; but this quantity of fluid is leſs than that naturally inherent in the rod; the rod will therefore remain undercharged, and hence the balls of the electrometer diverge with negative Electricity.

This explanation is the ſame as that mentioned in the preceding experiment, *viz.* in the method of electrifying an electrometer negatively, with a body poſſeſſed of poſitive electricity, &c.; but as this experiment is the baſis, or key, of ſeveral others, I ſhall inſiſt on it a little longer; and, to render its explanation more intelligible and clear, I ſhall make uſe of the following diagram:

A ——————— B.

Let the above-mentioned inſulated rod be repreſented by the line A B. When this rod is in its natural ſtate (in reſpect to Electricity) then the electric fluid belonging to it, is equally diffuſed throughout the rod. But when the excited tube is brought within three or four inches diſtance of one of the ends, for inſtance B, then the fluid, belonging to that end, will be driven to the end A; which end therefore becomes overcharged, and the end B undercharged; yet the rod has no more electric fluid now, than it had before; and when the tube is removed to ſome diſtance from the rod, the ſuperfluous fluid, repelled to the end A, returns to its former place, *i. e.* to the end B, and the equilibrium in the rod is reſtored. But if, when the fluid in the rod is repelled to the end A, this end be touched, the fluid repelled thither will immediately be conducted away by the body that touched it, and will leave the end A of the rod in a natural ſtate; but at the ſame time, the end B is undercharged; therefore, when the tube is removed, part of the natural fluid belonging to the end A, will go to the end B; and thus the whole rod will remain undercharged, *i. e.* negatively electrified.

If the above experiment be made with an electric negatively electrified (for inſtance, a rod of ſealing-wax inſtead of the excited glaſs tube) then the apparent Electricities in the rod will be juſt the reverſe of what they were before; for in this caſe, that end of the rod to which the electric has been preſented, will be overcharged, and the oppoſite end undercharged; which oppoſite end, if touched in this ſtate with ſome conducting ſubſtance, will acquire ſome electric fluid from that ſubſtance; and when, after that ſubſtance has been removed, the excited electric is alſo removed, the rod will remain overcharged.

In making this experiment, care muſt be taken that the end of the rod be very blunt, and that the electric be not very powerfully excited; otherwiſe a ſpark may paſs from this to the rod, which renders the experiment precarious.

EXPERIMENT VIII.

The two inſulated metallic Rods.

Take two rods of metal, each about a foot long, furniſhed with knobs at both ends, and, either by ſilk lines, or by inſulating ſtools, inſulate them, ſo that they may ſtand horizontally in one direction, and at about half an inch diſtance from one another. To the middle of each of theſe rods hang an electrometer, like that repreſented fig. 3. This done, take an excited glaſs tube, and bring it to about three inches diſtance from the knob of one of the rods; on doing which, the electrometers of both rods will appear electrified: keep the tube in that ſituation for about two ſeconds, then remove it. The rods now will remain electrified, as appears by the electrometers; the firſt, *viz.* that to which the excited tube had been preſented, remaining negative, and the other poſitive.

The reaſon of this phenomenon is, that when the tube was near the end of one of the rods, the action of its fluid repelling the fluid of that rod, cauſed it to paſs in a ſpark to the other contiguous rod; on which account, when the tube was removed, the firſt rod, having loſt ſome of its natural fluid, remained undercharged; and the other rod, acquiring the fluid loſt by the former, became overcharged.

In this experiment, if, inſtead of the glaſs tube, an electric, negatively excited, be brought near the end of one rod, then that rod will be electrified poſitively, and the other negatively; for the action of this electric, producing juſt the contrary effect of the glaſs tube, inſtead of repelling the fluid of the firſt rod into the ſecond, attracts that of the ſecond into the firſt.

In this experiment the electric does not communicate any electricity of its own, but only diſturbs the equilibrium between the fluid of the rods.

CHAP. VI.

Experiments on electric Light.

THE following experiments require to be made in the dark; for although the electric light, in ſeveral circumſtances, may be ſeen in the day-light, yet its appearance in this manner is very confuſed; and, that the Electrician might form a better idea of its different appearances, it is abſolutely neceſſary to perform ſuch experiments in a darkened room.

EXPERIMENT I.

The Star and Pencil of electric Light.

When the electrical machine is in good order, and the prime Conductor is ſituated with the collector ſufficiently near the glaſs cylinder (which ſituation I ſhall call hereafter its proper place) turn the winch, and you will ſee a lucid ſtar at each of the points of the collector. This ſtar is the conſtant appearance of the electric fluid that is entering a point. At the ſame time, you will ſee a ſtrong light proceeding from the rubber, and ſpreading itſelf over the ſurface of the cylinder; and, if the excitation of the cylinder is very powerful, denſe ſtreams of fire will proceed from the rubber, and, darting round almoſt half the circumference of the cylinder, will reach the points of the collector *.

If the chain of the rubber is taken off, and a pointed body (as for inſtance, the point of a needle or a pin) is preſented to the back of the rubber, at the diſtance of about two inches, a lucid pencil of rays will appear to proceed from the point preſented, and diverge towards the rubber.

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* If the prime Conductor is removed, the denſe ſtreams of fire will go quite round the cylinder; reaching from one ſide of the rubber to the other. — By obſerving on which ſide of the cylinder thoſe ſtreams are moſt copious, it may be eaſily determined which ſide of the rubber preſſes more or leſs upon the cylinder, or is better covered with amalgam, or, in ſhort, which ſide is the moſt or leaſt fit for the excitation of the glaſs.

This pencil is the conſtant appearance of the electric fluid iſſuing from a point; and in fact, it now comes out of the point, in order to ſupply the rubber, which is conſtantly exhauſted by the cylinder in motion.

If another pointed body be preſented to the prime conductor, it will appear illuminated with a ſtar; but if a pointed wire, or other pointed conducting body, be connected with the prime Conductor, it will throw out a pencil of rays; for the prime Conductor being overcharged, the fluid departing from it muſt, agreeably to the law, form a pencil on that point from which it flies off, and a ſtar on that point which it enters *.

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* It may be aſked, why the electric fluid entering a point, cauſeth the appearance of a ſtar; and when going out of the point, cauſeth the appearance of a bruſh of rays? In anſwer to this queſtion, F. BECCARIA ſuppoſes, that the ſtar is occaſioned by the difficulty with which the electric fluid is extricated from the air, which is an electric. Suppoſe, for inſtance, that a pointed wire is preſented to a body poſitively electrified, the electric fluid is firſt from that body commu-

F. BECCARIA remarks, that if two equally ſharp points are approached to a prime conductor, they will appear luminous at only half the diſtance at which one of them would have done.

From this experiment may be learned the method of diſtinguiſhing the quality of the Electricity of an electrified body, by the appearance of the electric light; for if a needle, or any other pointed body, be preſented in the dark, with the point towards a body ſtrongly electrified, it will appear illuminated with a ſtar, when that body is electrified poſitively, and with a pencil or bruſh, when it is electrified negatively.

Here it is proper to remark, that if two points (one of which is connected with the prime

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nicated to the air between it and the wire, and then the wire muſt extricate it from that air. The bruſh, he ſuppoſes to be occaſioned by the force with which the electric fluid, going out of a point, runs through the contiguous air to that which is more remote from it; *i. e.* by dividing the contiguous air, and not by affixing itſelf to it.

prime conductor, or the rubber) are oppoſed to one another, the appearance of light in both is pretty much the ſame. Mr. WILCKE remarks, that if a point not electrified, is oppoſed to another point electrified poſitively, the cones of light, which otherwiſe would appear upon them, diſappear; but that if a poſitive cone be oppoſed to a negative cone, they both preſerve their own characteriſtic properties *.

EXPERIMENT II.

Drawing Sparks.

Let the prime Conductor be ſituated in its proper place, and electrify it by working the machine; then bring a metallic rod with a round knob at each end, or the knuckle of a finger, within a proper diſtance of the prime Conductor, and a ſpark will be ſeen between that and the knuckle, or knobbed wire. The longer and ſtronger ſpark is drawn from that end of the prime

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* WILCKE, p. 140.—See BECCARIA's Art. Elect. § 941, and following.

Conductor which is fartheſt from the cylinder, or rather from the end of the knobbed rod I B, fixed at its end B, fig. 2.; for the electric fluid ſeems to acquire an impetus by going through a long Conductor, when electrified by a powerful machine *.

This ſpark (which has the ſame appearance, whether drawn from a prime Conductor poſitively, or negatively electrified) appears like a long line † of fire, reaching from the Conductor to the oppoſed body; and often (particularly when the ſpark is long, and different conducting ſubſtances are near the line of its direction) it will have the appearance of being bended to ſharp angles in different places, exactly reſembling a flaſh of lightning. Notwithſtanding, however, this extended appearance, which is imputed to the quick paſſage of the luminous matter, the electric fluid

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* The reaſon of this, I think, is, becauſe that end of the prime Conductor is leſs influenced by the atmoſphere of the excited cylinder.

† It often darts bruſhes of light ſideways, in every direction.

fluid paſſing from one body to another in a ſpark, is reaſonably thought to proceed in a ſeparate, and nearly globular body.

The direction of the ſpark often deceives the moſt experienced Electrician, it ſeeming ſometimes to proceed from one place, and at other times, under the ſame circumſtances, to proceed from the oppoſite. When the prime Conductor is electrified poſitively, the ſpark muſt certainly proceed from it, and go to the body preſented; and when the prime Conductor is electrified negatively, the ſpark muſt proceed from the body preſented, and go to the Conductor. This, however, we learn by reaſoning from other experiments; for the real direction of the ſpark in the above experiment, is much more rapid in its motion than to admit its form, much leſs its direction, to be perceived by our eyes.

A longer ſpark may be drawn from a larger than from a ſmaller Conductor, except when the Conductor exceeds a certain ſize. The Conductor, which, when put before an ordinary electrical machine, will give ſparks about equal in length to the diameter of the glaſs cylinder of the machine, is the largeſt that can be uſed to advantage; for a longer ſpark cannot be obtained, except in ſome particular caſes, *viz.* when ſome particles of duſt, or other extraneous matter, happen to be interpoſed between the Conductor and the braſs ball, or other ſubſtance, that is oppoſed to it, &c. as will appear from the following reaſoning:—The circumference of the glaſs cylinder is nearly equal to three times its diameter. The rubber, with its piece of ſilk, &c. may occupy about one third part of the ſaid circumference, and conſequently the collector of the Conductor, when put in the middle of the remaining ſurface, at moſt cannot be farther from the rubber than the length of one diameter of the cylinder, *viz.* one third part of the circumference; therefore it is plain, that if the cylinder could give a ſpark longer than the diameter of the cylinder, the ſpark would be darted to the rubber, rather than to any other body placed farther off from the Conductor.—When the rubber of the machine is made to communicate with the earth, by means of imperfect conductors, as a piece of wood, &c. then the Conductor will give a ſpark generally longer than when perfect conductors are employed for the ſaid communication. In this caſe it may happen, that a ſpark ſome ſmall matter longer than the diameter of the cylinder, might be obtained.

EXPERIMENT III.

The electric Light flaſhing between two metallic Plates.

Let two perſons, one ſtanding upon an inſulated ſtool, and communicating with the prime Conductor, and another ſtanding upon the floor, each hold in one of his hands a metal plate, in ſuch a manner, that the plates may ſtand back to back in a parallel ſituation, and about two inches aſunder. Let the winch of the machine be turned, and you will ſee the flaſhes of light between the two plates ſo denſe and frequent, that you may eaſily diſtinguiſh any thing in the room. By this experiment, the electric light is exhibited in a very copious and beautiful manner, and it bears a ſtriking reſemblance to lightning.

EXPERIMENT IV.

To fire inflammable Spirits.

The power of the electric ſpark to ſet fire to inflammable ſpirits, may be exhibited by ſeveral different methods; but more eaſily thus: — Hang to the prime Conductor a ſhort rod, having a ſmall knob at its end, then pour ſome ſpirit of wine, a little warmed, into a ſpoon of metal *; hold the ſpoon by the handle, and place it in ſuch manner, that the ſmall knob on the rod may be about one inch above the ſurface of the ſpirit. In this ſituation, if, by turning the winch, a ſpark be made to come from the knob, it will ſet the ſpirit on fire.

This experiment happens in the very ſame manner, whether the Conductor is electrified poſitively or negatively, *i. e.* whether the ſpark be made to come from the Conductor, or from the ſpoon; it being only in conſequence of the rapid motion of the ſpark that the ſpirits are kindled.

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* The readieſt way to warm the ſpirits for this experiment, is to ſet it on fire with a candle when it is in the ſpoon, and, after it has burned for about two ſeconds, to blow it out with your breath. In this ſtate it will be found very ready to take fire, even by a ſmall ſpark.

It will be perhaps ſcarce neceſſary to remark, that the more inflammable the ſpirits are, the more proper they will be for this experiment, as a ſmaller ſpark will be ſufficient to inflame them; therefore, rectified ſpirit of wine is better than common proof ſpirit, and æther better than either.

This experiment may be varied different ways, and may be rendered very agreeable to a company of ſpectators. A perſon, for inſtance, ſtanding upon an electric ſtool, and communicating with the prime Conductor, may hold the ſpoon with the ſpirits in his hand, and another perſon, ſtanding upon the floor, may ſet the ſpirits on fire, by bringing his finger within a ſmall diſtance of it. Inſtead of his finger, he may fire the ſpirits with a piece of ice; when the experiment will ſeem much more ſurprizing. If the ſpoon is held by the perſon ſtanding upon the floor, and the inſulated perſon brings ſome conducting ſubſtance over the ſurface of the ſpirit, the experiment ſucceeds as well.

"Mr. WINCKLER ſays, that oil, pitch, "and ſealing-wax, might be lighted by "electric ſparks, provided thoſe ſubſtances "were firſt heated to a degree next to "kindling. To theſe it muſt be added, "that Mr. GRALATH fired the ſmoke of "a candle juſt blown out, and lighted it "again; and that Mr. BOZE fired gun-"powder, melting it in a ſpoon, and firſt "the vapour that roſe from it *.

EXPERIMENT V.

The artificial Bolonian Stone illuminated by the electric Light.

The moſt curious experiment to ſhew the penetrability of the electric light, is made with the real, or with the artificial Bolonian ſtone, which is procured more eaſily, and was invented by the late Mr. J. CANTON. This phoſphorus is a calcareous ſubſtance, generally uſed in the form of a powder, which has the property of appearing lucid, when brought into the dark after having been expoſed to the light*.

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* PRIESTLEY's Hiſt. of Elect. period VII.

Take

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* The method of making this phoſphorus is as follows: "Calcine ſome common oyſter-ſhells" (if they are old, and half calcined by time, ſuch as are commonly found upon the ſea-ſhore, they are, as Mr. W. CANTON obſerves, ſo much the better) "by keeping them in a good coal-fire for half an hour, let the pureſt part of the calx be pulverized, and ſifted; mix with three parts of this powder one part of the flowers of ſulphur; let this mixture be rammed into a crucible of about an inch and a half in depth, till it be almoſt full; and let it be placed in the middle of the fire, where it muſt be kept red-hot for one hour at leaſt, and then ſet it by to cool: when cold, turn it out of the crucible, and cutting or breaking it to pieces, ſcrape off, upon trial, the brighteſt parts; which, if good phoſphorus, will be a white powder, and may be preſerved by keeping it in a dry phial with a ground ſtopple."

If this phoſphorus, whether in the phial or not, be kept in the dark, it will give no light, but if expoſed

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Take ſome of this powder, and, by means of ſpirit of wine, or æther, ſtick it all over the inſide of a clear glaſs phial, and ſtop it with a glaſs ſtopper, or a cork and ſealing-wax. If this phial be kept in a darkened room (which for this experiment muſt be very dark) it will give no light, but let two or three ſtrong ſparks be drawn from the prime Conductor, when the phial is kept at about two inches diſtance from the ſparks, ſo that it may be expoſed to that light, and this phial will receive that light, and afterwards will appear illuminated for a conſiderable time.

This powder may be ſtuck upon a board by means of the white of an egg, ſo as to repreſent figures of planets, letters, or any thing elſe, at the pleaſure of the operator, and theſe figures may be illuminated in the dark, in the ſame manner as the above-deſcribed phial.

to the light, either of the day, or of any thing elſe, and afterwards brought into a dark place, it will then appear lucid for a conſiderable time. For farther properties of this phoſphorus, ſee the Phil. Tranſ. Vol. LVIII.

A beautiful method to expreſs geometrical figures with the above phoſphorus, is to bend ſmall glaſs tubes of about the tenth part of an inch diameter, in the ſhape of the figure deſired, and then to fill them with the phoſphorus powder. Theſe may be illuminated in the manner deſcribed, and they are not ſo ſubject to be ſpoiled, as the figures repreſented upon the board frequently are.

The beſt method of illuminating this phoſphorus, and was that Mr. W. CANTON generally uſed, is to diſcharge a ſmall electric jar near it.

Paper, after being made dry and rather hot, marble, oyſter-ſhells, and moſt calcareous ſubſtances, eſpecially when burned to lime, have the property of being illuminated by the light given by the diſcharge of a jar, though not ſo much as the abovementioned phoſphorus.

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EXPERIMENT VI.

The luminous Conductor.

Fig. 6. Plate I. repreſents a prime Conductor invented by Mr. HENLY, which ſhews clearly the direction of the electric fluid paſſing through it, from whence it is called *the luminous Conductor* *. The middle part E F of this Conductor is a glaſs tube about eighteen inches long, and three or four inches in diameter. To both ends of this tube the hollow braſs pieces F D, B E, are cemented air-tight, one of which has a point C, by which it receives the electric fluid, when ſet near the excited cylinder of the electrical machine, and the other has a knobbed wire G, from which a ſtrong ſpark may be drawn; and from each of the pieces F D, B E, a knobbed wire proceeds, within the cavity of the glaſs tube. The braſs piece F D, or B E, is compoſed

of two parts, *i. e.* a cap F cemented to the glaſs tube, and having a hole with a valve, by which the cavity of the glaſs tube may be exhauſted of air; and the ball D, which is ſkrewed upon the cap F. The ſupporters of this inſtrument are two glaſs pillars faſtened in the bottom board H, like the prime Conductor repreſented fig. 2. When the glaſs tube of this Conductor is exhauſted of air by means of an air-pump, and the braſs ball is ſkrewed on, as repreſented in the figure, then it is fit for uſe, and may ſerve for a prime Conductor to an electrical machine.

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* An inſtrument much like this Conductor was ſome years ago contrived by Dr. WATSON, with which he made ſeveral original experiments upon the electric light.

If the point C of this Conductor is ſet near the excited cylinder of the machine, it will appear illuminated with a ſtar; at the ſame time the glaſs tube will appear all illuminated with a weak light; but from the knobbed wire, that proceeds within the glaſs from the piece F D, a lucid pencil will iſſue out, and the oppoſite knob will appear illuminated with a ſtar, which, as well as the pencil of rays, is very clear, and diſcernible among the other light, that occupies the greateſt part of the cavity of the tube.

If the point C, inſtead of being preſented to the cylinder, be connected with the rubber of the machine, the appearance of light within the tube will be reverſed; the knob which communicates with the piece F D appearing illuminated with a ſtar, and the oppoſite with a pencil of rays; becauſe in this caſe the direction of the electric fluid is juſt the contrary of what it was before; it then going from D to B, and now coming from B and going to D.

If the wires within the tube E F, inſtead of being furniſhed with knobs, be pointed, the appearance of light is the ſame, but it ſeems not ſo ſtrong in this, as in the other caſe.

EXPERIMENT VII.

The conducting Glaſs Tube.

Take a glaſs tube of about two inches diameter, and about two feet long; fix to one of its ends a braſs cap, and to the other a ſtop-cock, or a valve; then by means of an air-pump exhauſt it of air. If this tube be held by one end, and its other end be brought near the electrified prime Conductor, it will appear to be full of light, whenever a ſpark is taken by it from the prime Conductor; and much more ſo, if an electric jar be diſcharged through it.

This experiment may alſo be made with the receiver of an air-pump; take, for inſtance, a tall receiver, clean and dry, and through a hole at its top inſert a wire, which muſt be cemented air-tight. The end of the wire, that is within the tube, muſt be pointed, but not very ſharp; and the other end muſt be furniſhed with a knob. Put this receiver upon the plate of the air-pump, and exhauſt it. If now the knob of the wire at the top of the receiver be touched with the prime Conductor*, every ſpark will paſs through the receiver in a denſe and large body of light, from the wire to the plate of the air-pump.

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* When any thing is to be touched with the prime Conductor, that is not very portable, as the air-pump above-mentioned, the communication between the former and the latter may be made by means of a rod furniſhed with an electric handle, or the like.

It muſt be obſerved, that when the air is very much rarefied, the electric light in it is leſs denſe, though more diffuſed, and contrarywiſe.

EXPERIMENT VIII.

The Aurora Borealis.

Take a phial nearly of the ſhape and ſize of a Florence flaſk; fix a ſtop-cock or a valve to its neck, and exhauſt it of air as much as it is poſſible with a good air-pump. If this glaſs is rubbed in the common manner uſed to excite electrics, it will appear luminous within, being full of a flaſhing light, which plainly reſembles the aurora borealis, or northern light. This phial may alſo be made luminous by holding it by either end, and bringing the other end to the prime Conductor; in this caſe all the cavity of the glaſs will inſtantly appear full of flaſhing light, which remains in it for a conſiderable time after it has been removed from the prime Conductor.

Inſtead of the above-deſcribed glaſs veſſel, a glaſs tube, exhauſted of air and hermetically ſealed, may be uſed, and perhaps with better advantage. The moſt remarkable circumſtance of this experiment is, that if the phial or tube, after it has been removed from the prime Conductor (and even ſeveral hours after its flaſhing light hath ceaſed to appear), be graſped with the hand, ſtrong flaſhes of light will immediately appear within the glaſs, which often reach from one of its ends to the other.

The cauſes on which this experiment depend are two; firſt, the conducting nature of the vacuum; and, ſecond, the charging of the glaſs: for when one ſide of the glaſs phial is touched with the prime Conductor, the electric fluid, communicated to the outſide ſurface of one ſide of the phial, cauſeth the natural fluid belonging to the inſide ſurface to depart from its place, and go to the oppoſite ſide of the phial; and this fluid, paſſing through the vacuum, cauſes the light within the phial, which light is more or leſs ſubdivided, according as the vacuum is leſs or more perfect. Now, that part of the phial, which has touched the prime Conductor, is actually charged; for its outſide ſurface has acquired an additional quantity of electric fluid, and the inſide ſurface has loſt part of its own; but as the outſide of the phial has no coating, therefore, when it is removed from the prime Conductor, and is not graſped with the hand, or other Conductor, the charged part of the glaſs can be diſcharged only gradually; that is, whilſt its outſide ſurface is communicating its ſuperfluous fluid to the contiguous air, the inſide ſurface acquires the electric fluid from the other end of the phial, which fluid paſſing through the vacuum, cauſes that flaſhing, which is obſerved for ſo conſiderable a time. If the phial is graſped with the hand, its diſcharge is accelerated, hence the flaſhes within the phial appear more denſe and copious; yet it cannot be diſcharged all at once by this operation, becauſe the hand cannot touch every part of the glaſs at once,

EXPERIMENT IX.

The viſible electric Atmoſphere.

G I fig. 2. Plate II. repreſents the receiver with the plate of an air-pump. In the middle of the plate I F, a ſhort rod is fixed, having at its top a metal ball B nicely poliſhed, whoſe diameter is nearly two inches. From the top of the receiver, another rod A D with a like ball A proceeds, and is cemented air-tight in the neck C; the diſtance of the balls from one another being about four inches, or rather more. If, when the receiver is exhauſted of air, the ball A be electrified poſitively, by touching the top D of the rod A D with the prime Conductor or an excited glaſs tube, a lucid atmoſphere appears about it, which, although it conſiſts of a feeble light, is yet very conſpicuous, and very well defined; at the ſame time the ball B has not the leaſt light. This atmoſphere does not exiſt all round the ball A, but reaches from about the middle of it, to a ſmall diſtance beyond that ſide of its ſurface, which is towards the oppoſite ball B. If the rod with the ball A be electrified negatively, then a lucid atmoſphere, like the above-deſcribed, will appear upon the ball B, reaching from its middle to a ſmall diſtance beyond that ſide of it, that is towards the ball A; at the ſame time the negatively electrified ball A remains without any light.

The Operator in this experiment, muſt be careful not to electrify the ball A too much, for then the electric fluid will paſs in a ſpark from one ball to the other, and the experiment will not have the deſired effect. A little practice, however, will render the operation very eaſy and familiar. The exhauſtion muſt alſo be moderate; for Mr. WILSON, F. R. S. remarked, that no electric light would be ſeen in a vacuum made by means of one of Mr. SMEATON's air-pumps, which rarefied the air above 2000 times.

By this elegant experiment, which is of the celebrated F. BECCARIA, we have an ocular demonſtration of the theory of a ſingle electric fluid; we ſee that Electricity conſiſts of one uniform, homogeneous fluid, and not two, *viz.* the vitreous, and reſinous, as ſome have ſuppoſed; for if the poſitive and negative Electricity were two diſtinct fluids, attractive of one another, there ſhould, in the above experiment, always appear two atmoſpheres, *i. e.* one about the ball A, and another about the ball B; for when the ball A is overcharged with either fluid, it ſhould ſhew that ſuperfluous fluid on its ſurface, and this fluid ſhould attract towards the ball A, an atmoſphere of the contrary fluid from the ball B. But this, as we obſerved before, is not the caſe; for the appearance of the lucid atmoſphere is always on one ball, namely, that which is overcharged with the electric fluid; thus, when the ball A is electrified poſitively, the ſuperfluous fluid is viſible on that part of it which is neareſt to the ball B, becauſe B, being in a contrary ſtate of Electricity, endeavours to attract it; but, when the ball A is electrified negatively, it will attract the fluid proper to the ball B, which fluid on that account appears upon the ſurface of B, juſt in the act of leaping to the ball A.

In order to remove an error, that has been adopted by ſeveral writers on Electricity, it will be not amiſs in this chapter to mention, that the electric light has all the priſmatic colours, as well as the light of the ſun. This may be eaſily experienced by viewing an electric ſpark through a glaſs priſm *.

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* See Dr. PRIESTLEY's Hiſtory of Electricity, part VIII. ſec. XIII. n. XII.

CHAP. VII.

Experiments with the Leyden Phial.

EXPERIMENT I.

Of charging, and diſcharging a Phial in general.

TAKE a coated jar, as D E fig. 2, Plate I, and place it upon the table near the prime Conductor, ſo that the knob of its wire, and that only, may be in contact with it: fix the quadrant electrometer E fig. 2, upon the prime Conductor, and then turn the winch of the machine. You will obſerve, that as the jar is charging, the index of the electrometer will riſe gradually as far as 90°, or thereabouts, and then reſt: when this happens, you may conclude, that the jar has received its full charge. If now you take a diſcharging rod, and, holding it by the glaſs handle, apply firſt one of its knobs to the outſide coating of the jar, and then bring the other knob near the knob of the wire of the jar, or near the prime Conductor, that communicates with it, you will hear a report, and ſee very vivid ſparks between the diſcharging rod and the conducting ſubſtances, communicating with the ſides of the jar. This operation diſcharges the jar. If, inſtead of uſing the diſcharging rod, you touch the outſide of the jar with one hand, and bring the other hand near the wire of the jar, the ſame ſpark and report will follow, but now you will feel a ſhock, which affects your wriſts, elbows, and, if ſtrong, your breaſt alſo *. If a number of perſons join hands, and the firſt of them touches the outſide of the jar, and the laſt touches the wire communicating with the inſide, they will all feel the ſhock, and preciſely at the ſame perceivable time. This ſhock bearing no reſemblance to any ſenſation otherwiſe felt, cannot conſequently be deſcribed; and in order that a perſon may form a juſt idea of it, he muſt abſolutely feel it.

If many perſons lay hold of a metal plate that communicates with the outſide of a

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* A ſhock may be given to any ſingle part of the body, if that part only be brought into the circuit.

charged jar, and all together do alſo hold a metal rod with which the diſcharge is made, they will all feel the ſhock; which ſhews that the diſcharge has been made through ſeveral circuits at once.

The reaſon of the charging of the phial or jar in this experiment is, that when a ſuperfluous quantity of electric fluid is forced upon the inſide ſurface of the glaſs, it cauſeth an equal quantity of fluid, naturally inherent in the glaſs, to depart from the oppoſite ſurface, in conſequence of the repulſion natural to the particles of the electric fluid, which repulſion is exerted even through the glaſs; one ſide therefore of the glaſs remains overcharged, and the other undercharged; as ſoon, therefore, as the communication between the two ſides of the jar is compleated, the ſuperfluous fluid on one ſide of the glaſs flies violently to the other ſide, and the rapidity of its motion occaſions the ſpark, the report, &c.

If the coated jar be held by the wire communicating with its inſide, and the outſide coating be preſented to the prime

Conductor, it will be charged as readily as in the other method, but with this difference, that in this caſe the outſide will be poſitive, and the inſide negative.

We have ſuppoſed above, that the prime Conductor was electrified poſitively; but if the experiment be repeated when the Conductor, by being connected with the rubber of the machine, is electrified negatively, the jar would in the ſame manner be charged; except that in this caſe the ſide that touches the prime Conductor would be electrified negatively, and the oppoſite ſide poſitively.

EXPERIMENT II.

To ſhew that an inſulated Jar cannot be charged.

Set a coated jar upon an electric ſtool; connect its wire, or its outſide coating with the prime Conductor, and turn the winch of the machine. You will then obſerve, that the index of the quadrant electrometer, placed upon the prime Conductor, ſoon riſes to 90°, ſeemingly ſhewing that the jar is charged. Then remove the electric ſtool with the jar from the prime Conductor, and either with a diſcharging rod, or with your hands, endeavour to diſcharge the jar, and you will find, that it is not charged; for no remarkable ſpark, no ſhock, nor any other phenomenon of charged glaſs, will appear.

The reaſon why in this experiment the inſide of the jar could acquire no additional electric fluid, and therefore the jar could acquire no charge, is becauſe the outſide could not at the ſame time part with its own fluid, its communication with the earth being cut off by the electric ſtool. But repeat this experiment with only this variation, that, by means of a chain or otherwiſe, the outſide of the jar be made to communicate with the table, and you will then find, that the jar will be charged; for in this caſe the fluid, naturally inherent in the outer ſurface of the jar, can readily be repelled through the chain, &c. into the table.

Strictly ſpeaking, the jar in this experiment will acquire a very ſlight charge, becauſe ſome of the electric fluid belonging to its outſide will be imparted to the air, &c.

If a jar be inſulated, and one ſide of it, inſtead of being connected with the earth, be connected with the inſulated rubber, whilſt the other ſide communicates with the prime Conductor, the jar will be alſo charged, and perhaps in a more expeditious manner; for whilſt the rubber exhauſts one ſide, the other ſide is ſupplied by the prime Conductor. In this manner it is ſhown, that the jar is charged with its own fluid, *i. e.* the natural electric fluid of one of its ſides is, by the action of the machine, thrown on the other ſide.

EXPERIMENT III.

The preceding Experiment diverſified.

To make the above experiment in a clearer, and more ſatisfactory manner, place the jar upon the ſtool as before, and with its wire not in contact, but at about half an inch diſtance from the prime Conductor; hold the knob of another wire at ſuch a diſtance from the outſide coating of the jar, as the knob of the jar is from the prime Conductor, then let the winch of the machine be turned, and you will obſerve, that whenever a ſpark comes from the prime Conductor to the wire of the jar, another ſpark paſſes from the outſide coating of the jar to the knob of the wire preſented towards it; which ſhews, that as a quantity of electric fluid is entering the inſide of the jar, an equal quantity of it is leaving the outſide. In this manner the jar becomes charged.

If inſtead of the knobbed wire, a pointed one be preſented to the outſide of the jar, it will appear illuminated with a ſtar; and if inſtead of preſenting any wire to the jar, a pointed wire be connected with its coating, it will appear illuminated with a bruſh of rays (*i. e.* by throwing the electric fluid into the air), which will laſt as long as the jar is charging.

If the knob of another jar be preſented to the outſide coating of the inſulated jar in the above experiment, it will alſo be charged; for the fluid, going out of the outſide coating of the firſt jar, *i. e.* that ſtanding upon the ſtool, will go in the inſide of the other jar, and cauſe the fluid, inherent to the outſide of that jar, to depart from its place [*].

EXPERIMENT IV.

To ſhew that the Charge of a Jar, or Glaſs in general, does not reſide in the Coating.

Take a naked phial, and for a coating on the outſide ſtick a piece of tin-foil, with a little tallow or bees-wax, ſo that it can juſt adhere to the glaſs; and for an inſide coating uſe ſmall leaden ſhot, or quickſilver; laſtly, inſert through its neck a knobbed wire communicating with the ſhot or quickſilver.—This done, hold the phial thus coated by its outſide coating, and charge it, by preſenting its knobbed wire to the prime Conductor. When it is charged, turn it upſide down, and let its wire and quickſilver, or ſhot, fall in a glaſs receiver; then remove its outſide coating alſo. In this operation the phial does not loſe its charge, and if you examine the quickſilver or ſhot, you will find that it contains no more Electricity than any other like conducting inſulated body, which has been in contact with the prime Conductor, would contain. Replace the outſide coating again upon the phial, pour the ſhot or quickſilver again into it, or any other conducting ſubſtance, then touch with one hand the outſide coating, and with the other, by introducing a finger or a wire, touch the inſide non-electric, and you will feel a ſhock; which will convince you, that the glaſs has loſt very little of its charge by the operation above-mentioned.

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[*] It is eaſy to underſtand from this experiment, how ſeveral phials may be connected together, ſo that they may be charged all at once, with nearly the ſame trouble as one is charged. It muſt, however, be obſerved, that when ſeveral jars are ſo connected, that the inſide of one communicates with the outſide of another, &c. they cannot be charged ſo high, nor ſo eaſily, as otherwiſe; the difficulty increaſing nearly in proportion to the number of the jars.

The ſame experiment may be more conveniently made by laying a pane of glaſs upon a metal plate, and covering an equal part of the upper ſurface with tin-foil, having a ſilk thread faſtened to one of its ſides, by which it may be eaſily taken off, when the glaſs is charged, and as eaſily replaced, when required.

EXPERIMENT V.

To prove that the electric Fluid does not expel the Air contained in a Phial.

Through a hole made in the cork that ſtops a coated phial, introduce a ſmall glaſs tube open at both ends, and of about one thirtieth part of an inch in diameter; bend that part of the tube, that is out of the phial, in an horizontal ſituation, and with bees-wax faſten the cork ſo, that no air can get in or out of the phial, except it paſſes through the glaſs tube; laſtly, put a ſmall drop of red wine, or ink, in the horizontal part of the tube, ſo that it may be eaſily moved through it, by the leaſt rarefaction or condenſation of the air within the phial.

If this phial thus furniſhed be charged, by connecting the prime Conductor with its wire, the drop of liquor in the glaſs tube will not be ſtirred from its ſituation; which ſhews that the electric fluid, immitted into the phial, does not exclude any of the air that the phial contains. If the phial be diſcharged, the drop of liquor in the tube will be often puſhed a little out of its place, and afterwards return to its former ſituation; which ſhews, that on making the diſcharge, the air within the phial was a little diſplaced, or rarefied. This however is to be imputed to ſome ſpark, that generally happens within the cavity of the phial, on account that the wire is not in perfect contact with the inſide coating*.

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* Having repeated this experiment with a ſmall phial, whoſe charging-piece (as we may call it) was a production of the inſide coating, (which was of one piece of tin-foil, ſtuck to the glaſs with bees-wax, in conſequence of which no ſpark could happen within the phial) I found that the drop of liquor in the glaſs tube was not ſtirred, either in charging or diſcharging the phial.

EXPERIMENT VI.

The Courſe of the electric Fluid in the Diſcharge rendered viſible by the Star and Pencil.

When a jar is charged, take a diſcharging rod having its ends pointed, *i. e.* the diſcharging rod repreſented in fig. 10. Plate I. without its knobs, and keep it as repreſented, fig. 11. that is, in ſuch a ſituation, that one of its points C may be at about one inch diſtance from the knob A, and the other point B at an equal diſtance from the outſide coating of the jar; by theſe means the jar will be diſcharged ſilently; and if its inſide be electrified poſitively, you will ſee, that the point C of the diſcharging rod is illuminated with a ſtar, and the point B with a pencil; becauſe, in this caſe, the electric fluid, going from the inſide to the outſide of the jar, enters the point C, and iſſues from the point B. But if the jar is electrified negatively on the inſide, and conſequently poſitive on the outſide, then the pencil of rays will appear upon the point C, and the ſtar upon the point B; for in this caſe the electric fluid paſſes from the outſide to the inſide of the jar.

N. B. This experiment, as well as any other, in which the electric light is to be obſerved, requires to be made in the dark.

EXPERIMENT VII.

The Courſe of the electric Fluid in the Diſcharge ſhewn by the Flame of a Wax-taper.

Remove the circular piece of wood E from the univerſal diſcharger, repreſented fig. 5. Plate I. Fix the wires D B, D C, ſo that their knobs D D may be about two inches diſtance from one another; and upon the ſocket F fix a piece of wax-taper lighted, ſo that its flame may be juſt in the middle, between the knobs D D. Having diſpoſed the apparatus in this manner, if you connect, by means of a chain or otherwiſe, the outſide of a charged jar with one of the wires C, and bring the knob of the jar to the other wire C, you will obſerve, that on making the diſcharge, which muſt paſs between the knobs D D, the flame of the wax-taper is always driven in the direction of the electric fluid; that is, it will be blown upon the knob of that wire, which communicates with that ſide of the jar which is negatively electrified.

In this experiment, the jar muſt have an exceeding ſmall charge, juſt ſufficient to paſs through the interval in the circuit; which experience will preſently determine; otherwiſe the experiment will not ſucceed, or be perhaps rendered equivocal *.

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* If it be aſked, Why this experiment does not ſucceed with a great exploſion as well as with a very ſmall one? the anſwer is, that when a jar highly charged, is brought near one of the wires of the univerſal diſcharger, it creates an atmoſphere about the knob of the ſaid wire, which atmoſphere diſturbs the flame of the wax taper, before the actual diſcharge; beſides, the electric fluid in a great exploſion, by its elaſtic nature, paſſes through the flame of the wax-taper too ſwiftly to communicate to it any viſible motion; in the ſame manner as a bullet, diſcharged from a piſtol againſt an open door, makes a hole through the door without ſhutting it.

EXPERIMENT VIII.

The Courſe of the electric Fluid in the Diſcharge, rendered conſpicuous by the Motion communicated to a Pith Ball.

Bend a card, length-ways, over a round ruler, ſo as to form a channel, or ſemicircular groove *: lay this card upon the circular board E of the univerſal diſcharger, repreſented fig. 5. of Plate I. and in the middle of it put a pith-ball of about half an inch diameter; then at equal diſtances, about half or three quarters of an inch from the pith-ball, lay the two braſs knobs D D. The card being perfectly dry, and rather hot, if you connect, by means of a chain or otherwiſe, the outſide of a charged jar with one of the wires C, and bring the knob of the jar to the other wire C, you will obſerve, that on making the diſcharge, which muſt paſs between the knobs D D, and over the card, &c. the pith-ball is always driven in the direction of the electric fluid; *i. e.* it is puſhed towards that knob which communicates with the negative ſide of the jar.

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* Inſtead of the card, a piece of baked wood may be cut in that ſhape, and painted over with lamp-black and oil; which will anſwer better than the card, it being much more ſteady, and not ſo liable to attract moiſture.

It muſt be obſerved, that in this experiment the charge of the jar muſt be juſt ſufficient to paſs through the interval in the circuit; the card, or piece of baked wood, muſt be very dry and clean; and, in ſhort, the diſpoſition of the apparatus, and the performance of this curious experiment, require a degree of nicety that can only be obtained by practice. Without great precaution, it ſometimes fails; but when the operator has once got it to ſucceed, and follows exactly the ſame method of operation, he may be ſure that the event of the experiment will be conſtantly as above-deſcribed.

EXPERIMENT IX.

The Leyden Vacuum.

Fig. 8 and 9. of Plate I. repreſent a ſmall phial coated on the outſide about three inches up the ſides with tin-foil; at the top of the neck of this phial, a braſs cap is cemented, having a hole with a valve, and from the cap a wire proceeds a few inches within the phial, terminating in a blunt point. When this phial is exhauſted of air, a braſs ball is ſcrewed upon the braſs cap, ſo as to defend the valve, and prevent any air from getting into the exhauſted glaſs *. This phial exhibits clearly the direction of the electric fluid, both in charging and diſcharging; for if it be held by its bottom, and its braſs knob be preſented to the prime Conductor poſitively electrified, you will ſee that the electric fluid cauſeth the pencil of rays to proceed from the wire within the phial, as repreſented fig. 9. and if it is diſcharged, a ſtar will appear in the place of the pencil, as repreſented in fig. 8. But if the phial is held by the braſs cap, and its bottom be touched with the prime Conductor, then the point of the wire, on its inſide, will appear illuminated with a ſtar when charging, and with a pencil when diſcharging. If it be preſented to a prime Conductor electrified negatively, all theſe appearances, both in charging and diſcharging, will be reverſed.

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* The inſide of this phial requires no coating, becauſe, as the electric fluid pervades vacuum, it can paſs freely from the wire to the ſurface of the exhauſted glaſs, without the help of a non-electric coating.

This experiment of the Leyden vacuum, together with the two preceding ones, namely the ſeventh and eighth of this chapter, are inventions of Mr. HENLY.

EXPERIMENT X.

To pierce a Card, and other Subſtances, with the electric Exploſion.

Take a card, a quire of paper, or the cover of a book, and keep it cloſe to the outſide coating of a charged jar; put one knob of the diſcharging rod upon the card, quire of paper, &c. ſo that between the knob and coating of the jar, the thickneſs of that card, or quire of paper only is interpoſed; laſtly, by bringing the other knob of the diſcharging rod near the knob of the jar, make the diſcharge; and the electric matter ruſhing through the circuit, from the poſitive to the negative ſurface of the jar, will pierce a hole (or perhaps ſeveral) quite through the card, or quire of paper *. This hole has a bur raiſed on each ſide, except the card, &c. be preſſed hard between the diſcharging rod and the jar; which ſhows that the hole is not made in the direction of the paſſage of the fluid, but in every direction from the center of the reſiſting body.

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* The hole, or holes, are larger or ſmaller, according as the card, &c. is more damp or more dry. It is remarkable, that if the noſtrils are preſented to it, they will be affected with a ſulphureous, or rather a phoſphoreal ſmell, juſt like that produced by an excited Electric.

If this experiment be made with two cards inſtead of one, which however muſt be kept very little diſtant from one another *, each of the cards, after the exploſion, will be found pierced with one or more holes, and each hole will have burs on both ſurfaces of each card.

If, inſtead of paper, a very thin plate of glaſs, roſin, ſealing-wax, or the like, be interpoſed between the knob of the diſcharging rod, and the outſide coating of the jar, on making the diſcharge, this will be broken in ſeveral pieces.

Small inſects may alſo be killed in this manner; they may be held between the

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* This may be eaſily effected by bending one of the cards a little.

outſide coating of the jar, and the knob of the diſcharging rod, like the above card; and a ſhock of a common phial ſent through them, will inſtantly deprive them of life, if they are pretty ſmall; but if larger, they will be affected in ſuch a manner, as to appear quite dead on firſt receiving the ſtroke, but will, after ſome time, recover: this, however, depends on the quantity of the charge ſent through them.

If a ſhock is ſent through a lump of white ſugar, ſtrong enough to break the ſugar, the ſhock will illuminate every piece of it, ſo as to afford a beautiful experiment in the dark.—The ſugar will give light for about a minute afterwards.

EXPERIMENT XI.

To ſhew the Effect of the Shock ſent over the Surface of a Card or other Subſtances.

Put the extremities of two wires upon the ſurface of a card, or other body of an electric nature, ſo that they may be in one direction, and about one inch diſtance from one another; then, by connecting one of the wires with the outſide of a charged jar, and the other wire with the knob of the jar, the ſhock will be made to paſs over the card or other body.

If the card be made very dry, the lucid track between the wires will be viſible upon the card for a conſiderable time after the exploſion. If a piece of common writing-paper be uſed inſtead of the card, it will be torn by the exploſion into very ſmall bits.

If inſtead of the card, the exploſion is ſent over the ſurface of a piece of glaſs, this will be marked with an indelible track, which generally reaches from the extremity of one of the wires to the extremity of the other. In this manner the piece of glaſs is very ſeldom broken by the exploſion. But Mr. HENLY has diſcovered a very remarkable method to increaſe the effect of the exploſion upon the glaſs; which is by preſſing with weights that part of the glaſs, which lies between the two wires, (*i. e.* that part, over which the ſhock is to paſs). He puts firſt a thick piece of ivory upon the glaſs, and places upon that ivory a weight at pleaſure, from one quarter of an ounce, to ſix pounds: The glaſs in this manner is generally broken by the exploſion into innumerable fragments, and ſome of it is abſolutely reduced into an impalpable powder. If the glaſs is very thick, and reſiſts the force of the exploſion, ſo as not to be broken by it, it will be found marked with the moſt lively priſmatic colours, which are occaſioned by very thin laminæ of the glaſs, in part ſeparated from it by the ſhock. The weight laid upon the glaſs is always ſhook by the exploſion, and ſometimes it is thrown quite off from the ivory*. This experiment may be moſt conveniently made with the univerſal diſcharger. Fig. 5. of Plate I.

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* If ſmall repreſentations of houſes, &c. be laid upon a board, placed on the piece of ivory; that, being ſhook by the exploſion, will give a very natural idea of an earthquake.

EXPERIMENT XII.

To ſhew the Direction of the electric Fluid in the Diſcharge, by cauſing the Shock to go over the Surface of a Card.

Diſpoſe the apparatus in the manner deſcribed in the preceding experiment, but with this difference, that inſtead of laying the extremities of both wires upon the ſame ſide of the card, one of them be placed under the card; then ſend a ſhock through the ſaid wires, as in the preceding experiment, and you will obſerve, that the electric fluid will run over that ſurface of the card, upon which lies the extremity of that wire, which is connected with the poſitive ſide of the jar; and in order to paſs to the extremity of the other wire, it will break a hole through the card juſt over the extremity of that wire, which is connected with the negative ſide of the jar.

This excellent experiment, which ſhows the direction of the electric fluid in the diſcharge of a jar, is a diſcovery of Mr. LULLIN of Geneva.

N. B.

N. B. With very large jars, this experiment has been obſerved to pierce ſeveral holes, and in ſuch manner as to render the experiment not ſatisfactory.

EXPERIMENT XIII.

To ſwell the Clay, and break ſmall Tubes with the electric Exploſion.

Roll up a piece of ſoft tobacco-pipe clay in a ſmall cylinder C D fig. 4. Plate II. and inſert in it two wires A, B, ſo that their ends within the clay may be about a fifth part of an inch from one another. If a ſhock be ſent through this clay, by connecting one of the wires A, or B with the outſide of a charged jar, and the other with the inſide, it will be inflated by the ſhock, *i. e.* by the ſpark, that paſſes between the two wires, and after the exploſion will appear as repreſented fig. 5. If the ſhock ſent through it is too ſtrong, and the clay not very moiſt, it will be broken by the exploſion, and its fragments ſcattered in every direction.

To make this experiment with a little variation, take a piece of the tube of a tobacco-pipe, about one inch long, and fill its bore with moiſt clay, then inſert in it two wires, as in the above rolled clay, and ſend a ſhock through it. This tube will not fail to burſt by the force of the exploſion, and its fragments will be ſcattered about to a great diſtance.

If inſtead of clay, the above-mentioned tube of the tobacco-pipe, or a glaſs tube, (which will anſwer as well) be filled with any other ſubſtance, either electric or non-electric, inferior to metal, on making the diſcharge, it will be broken in pieces with nearly the ſame force.

This experiment is the invention of Mr. LANE, F. R. S.

EXPERIMENT XIV.

To ſhow the Courſe of the electric Fluid by the ſpontaneous Diſcharge.

Take a coated phial of a ſmall ſize, and if the naked part of it, *i. e.* from its outſide

ſide coating to the cork, is very dry, breathe upon it once or twice, ſo as to render it ſlightly damp; then holding the phial by its outſide coating, preſent its knob to the prime Conductor, while the machine is in action, and you will ſee, that after the phial has received a ſmall charge, a beautiful bruſh of rays will proceed from the cork, which, after going a little way into the air, turns its courſe towards the outſide coating of the phial. If the phial, inſtead of the prime Conductor, be preſented to the inſulated rubber, then the bruſh, inſtead of proceeding from the cork, will iſſue from the outſide coating, and direct its courſe towards the cork or wire of the phial; ſhowing beyond a doubt the truth of the hypotheſis of a ſingle electric fluid.

This experiment, which is of Mr. HENLY, requires a nicety of operation, without which it will not ſucceed as above deſcribed. The quantity of moiſture upon the phial, and the quantity of Electricity communicated by the machine, muſt be of a degree, which nothing but practice can determine.

EXPERIMENT XV.

To make the electric Spark viſible in Water.

Fill a glaſs tube of about half an inch diameter, and ſix inches long, with water, and to each extremity of the tube adapt a cork, which may confine the water; through each cork inſert a blunt wire, ſo that the extremities of the wires within the tube may be very near one another; laſtly, connect one of theſe wires with the coating of a ſmall charged phial, and touch the other wire with the knob of it; by which means the ſhock will paſs through the wires, and cauſe a vivid ſpark to appear between their extremities within the tube. In performing this experiment care muſt be taken, that the charge be exceedingly weak, otherwiſe the tube will burſt.

C fig. 14. Plate II. repreſents a common drinking-glaſs almoſt full of water. A B are two knobbed wires ſo bent, that their knobs may be within a little diſtance of one another in the water. If one of theſe wires be connected with the outſide coating of a pretty large jar, and the other wire be touched with the knob of it; the exploſion which muſt paſs through the water from the knob of one of the wires to that of the other, will diſperſe the water, and break the glaſs with a ſurpriſing violence. This experiment is very dangerous, if not conducted with great caution.

F. BECCARIA conſtructed a ſmall mortar, into which a drop of water was put, between the extremities of two wires which went through the ſides of the mortar, and a wooden ball was applied over the drop of water; then a charged jar being diſcharged through the wires of the mortar, and conſequently through the drop of water, rarefied the latter, and drove the ball out with conſiderable force. Mr. LULLIN produced a greater effect by making the diſcharge through oil inſtead of water. *Diſſertatio Phyſica*, p. 26.

EXPE-

EXPERIMENT XVI.

To prove that the electric Spark diſplaces and rarefies the Air.

Fig. 3. Plate II. repreſents an inſtrument, which the inventor, Mr. KINNERSLEY, calls the *electrical Air Thermometer*, it being very uſeful to obſerve the effects of the electric exploſion upon air. The body of this thermometer conſiſts of a glaſs tube A B, about ten inches long, and nearly two inches diameter, and cloſed air-tight at both ends by two braſs caps. Through a hole in the upper cap, a ſmall tube H A, open at both ends, is introduced in ſome water at the bottom B of the large tube. Through the middle of each of the braſs caps, a wire F G, E I is introduced, having a braſs knob within the glaſs tube, and by ſliding through the caps, they may be ſet at any diſtance from one another. This inſtrument is, by a braſs ring C, faſtened to the pillar of the wooden ſtand C D, that ſupports it. When the air within the

tube A B is rarefied, it will preſs upon the water at the bottom of the tube, which will conſequently riſe in the cavity of the ſmall tube; and as this water riſes higher or lower, ſo it ſhows the greater or leſs rarefaction of the air within the tube A B, which has no communication with the external air.

If the water, when this inſtrument is to be uſed, is all at the bottom of the large tube, (*i. e.* none of it is in the cavity of the ſmall tube) it will be proper to blow with the mouth into the ſmall tube, and thus cauſe the water to riſe a little in it; where, for better regulation, a mark may be fixed.

Bring the knobs G I of the wires I E, F G into contact with one another, then connect the ring E, or F with one ſide of a charged jar, and the other ring with the other ſide, by which operation a ſhock will be made to paſs through the wires F G, I E, *i. e.* between the knobs E I. In this caſe you will obſerve, that the water in the ſmall tube is not at all moved from the mark; which ſhows, that the paſſage of the electric fluid through Conductors ſufficiently large, occaſions no rarefaction, nor diſplaces the air about them.

Put the knobs G, I a little diſtant from one another, and ſend a ſhock through them as before, and you will ſee that the ſpark between the two knobs, not only diſplaces, but rarefies conſiderably the air; for the water will be ſuddenly puſhed almoſt to the top of the ſmall tube, and immediately it will ſubſide a little, as for inſtance as far as H; which is occaſioned by the ſudden diſplacing and replacing of the air about the place, where the ſpark appeared within the tube A B. After that the water has ſubſided ſuddenly from the firſt riſing, it will then gradually and ſlowly come down to the mark at which it ſtood before the exploſion; which is the effect of the air that was rarefied, and which gradually returns to its former temperature.

If this experiment be made in a room, where the degree of heat is variable, then proper allowance muſt be made for this circumſtance, in eſtimating the event of the experiment; for the electrical air thermometer is affected by heat, or cold in general, as well as by that cauſed by an electric ſpark.

EXPERIMENT XVII.

To fire Gun-powder.

Make a ſmall cartridge of paper, and fill it with gun-powder, or elſe fill the tube of a quill with it; inſert two wires, one at each extremity, ſo that their ends within the quill, or cartridge, may be about one fifth of an inch from one another; this done, ſend the charge of a phial through the wires, and the ſpark between their extremities, that are within the cartridge, or quill, will ſet fire to the gun-powder. If the gun-powder be mixed with ſteel-filings, it will take fire more readily, and with a very ſmall ſhock.

EXPERIMENT XVIII.

To light a Candle by the diſcharge of a Jar.

Take a wire of the ſize of a common knitting-needle, and by means of a ſmall flexible wire or a chain, let one end of it communicate with the outſide of a jar, that at leaſt contains about 10 inches of coated ſurface. To the other end of the thick wire ſome cotton muſt be twiſted, but very looſely, ſo as to form a head round, and to conceal the extremity of the wire entirely. This head of cotton muſt be rolled in powder of lycopodium, or, which anſwers better, in powder of roſin; by which means a good deal of the powder will ſtick to the cotton: — this done, the jar is charged, and then the head of cotton, &c. is brought towards its knob rather quickly, ſo as to cauſe the jar to diſcharge through the cotton, by which means the cotton will be inſtantly ſet on fire, and will laſt long enough to light a candle thereby. — This is a very ſtriking experiment, contrived by Dr. INGENHOUSZ.

EXPERIMENT XIX.

To ſtrike Metals into Glaſs.

Take two ſlips of common window-glaſs about three inches long, and half an inch wide; put a ſmall ſlip of gold, ſilver, or braſs leaf, between them, and tie them together, or elſe preſs them together between the boards of the preſs H, belonging to the univerſal diſcharger, fig. 5, Plate I. leaving a little of the metallic leaf out between the glaſſes at each end; then ſend a ſhock through this metallic leaf, and the force of the exploſion will drive part of the metal into ſo cloſe a contact with the glaſs, that it cannot be wiped off, or even be affected by the common menſtrua, which otherwiſe would diſſolve it.

In this experiment the glaſſes are often ſhattered to pieces; but whether they are broken or not, the indelible metallic tinge will always be found in ſeveral places, and ſometimes through the whole length of both glaſſes.

EXPERIMENT XX.

To ſtain the Paper, or Glaſs.

Lay a chain, which forms a part of the circuit between the two ſides of a charged jar, upon a ſheet of white paper, and if a ſhock be ſent through it, the paper will be found ſtained with a blackiſh tinge at every juncture of the links. If the charge be very large, the paper, inſtead of being ſtained with ſpots, is burnt through. If the chain be laid upon a pane of glaſs, inſtead of paper, the glaſs will often be found ſtained with ſpots in ſeveral places, but (as might be expected) not ſo deep as the paper.

If this experiment be made in the dark, a ſpark will be ſeen at every juncture of the links; and if the links are ſmall, and the ſhock pretty ſtrong, the chain will appear illuminated like a line of fire; which ſhows that the electrical fluid meets with ſome reſiſtance in paſſing from one link of the chain to another.

EXPERIMENT XXI.

The lateral Exploſion.

If a jar be diſcharged with a diſcharging rod that has no electric handle, the hand that holds it, in making the diſcharge, feels ſome kind of ſhock, eſpecially when the charge is conſiderable.——In other words: A perſon, or any conducting ſubſtance, that is connected with one ſide of a jar, but forms no part of the circuit, will feel a kind of ſhock, *i. e.* ſome effect of the diſcharge. This may be rendered viſible in the following manner. Connect with the outſide of a charged jar a piece of chain; then diſcharge the jar through another circuit, as for inſtance, with a diſcharging rod in the common way, and the chain that communicates with the outſide of the jar, and which makes no part of the circuit, will appear lucid in the dark, *i. e.* ſparks will appear between the links; which ſhews that the electric fluid natural to that chain, muſt by ſome means have been diſturbed. This chain will alſo appear luminous, if it is not in contact with the outſide of the jar, but only very near it; and on making the diſcharge, a ſpark will be ſeen between the jar and the end of the chain near it. This electrical appearance out of the circuit of a diſcharging jar, is that which we call the *lateral Exploſion*: and to make it appear in the moſt conſpicuous manner, obſerve the following method, which is of Dr. PRIESTLEY.

When a jar is charged, and ſtands upon the table as uſual, inſulate a thick metallic rod, and place it ſo that one of its ends may be contiguous to the outſide coating of the jar; and within about half an inch of its other end, place a body of about ſix or ſeven feet in length, and a few inches in breadth; then put a chain upon the table, ſo that one of its ends may be about one inch and a half diſtant from the coating of the jar; at the other end of the chain apply one knob of the diſcharging rod, and bring the other knob to the wire of the jar in order to make the exploſion. On making the diſcharge in this manner,

a ſtrong

a ſtrong ſpark will be ſeen between the inſulated rod, which communicates with the coating of the jar, and the body near its extremity, which ſpark does not alter the ſtate of that body in reſpect to Electricity; hence it is imagined, that this lateral ſpark flies from the coating of the jar, and returns to it at the ſame inſtant, allowing no perceptible ſpace of time, in which an electrometer can be affected. Whether this lateral exploſion is received on flat and ſmooth ſurfaces, or upon ſharp points, the ſpark is always equally long and vivid.

The cauſe of this phenomenon ſeems to be the interruption in the circuit, made by introducing bad Conductors into it; for, as this interruption is greater or leſs, ſo the lateral exploſion is more or leſs conſiderable.

CHAP. VIII.

Experiments with other charged Electrics.

THAT the experiments made with other charged electrics are ſimilar to thoſe made with charged glaſs, is very evident: ſince it has been obſerved above in the Firſt Part, and alſo in the experiments already deſcribed, that the property of being charged, of exploding, &c. is not inherent in glaſs, as glaſs, but, as being impervious to the electric fluid; and in conſequence, it muſt be common to all ſuch ſubſtances, which, like glaſs, are impervious to that fluid: therefore, under the title of experiments with other electrics, I mean to deſcribe experiments, not of a different nature from the above-mentioned, but only the manner of coating and uſing other electrics, which are not ſo manageable as glaſs, but at the ſame time, have ſome peculiar advantages. Theſe methods I ſhall reduce to three, *i. e.* firſt, that of making the noble experiment of charging a plate of air; ſecondly, the method of coating reſinous ſubſtances; and laſtly, a method of trying other electrics, that are in a fluid ſtate.

EXPERIMENT I.

To charge a Plate of Air.

Take two ſmooth circular boards, quite plain, and each about three or four feet in diameter; coat one ſide of each with tin-foil, which ſhould be paſted down, and burniſhed, and turned over the edge of the board. Theſe boards muſt be both inſulated, parallel to one another, in an horizontal poſition; they muſt be turned with their coated ſides towards each other, and ſhould be placed in ſuch a manner as to be eaſily removed to or from each other; to do which, it will be proper to fix to one of the boards a ſtrong ſupporter, of glaſs or baked wood, and to ſuſpend the other by ſilk ſtrings from the cieling of the room; from which, by a proper pulley, it may be lowered or raiſed, ſo as to be at any diſtance required from the lower board, which may be placed upon the table.

When theſe boards are placed in the manner above deſcribed, and at about one inch diſtance from one another, they may be uſed exactly as the two coatings of a pane of glaſs. If one of the boards is connected with the electrified prime Conductor, and the other be left inſulated, they will receive no charge, agreeable to the ſecond experiment of the preceding chapter; and if after ſome time you touch them, you will receive only a ſpark from the upper board, in conſequence of its being connected with the electrified prime Conductor. If, whilſt one of the boards is receiving Electricity, the other communicates with the earth, then the plate of air between them will be charged, like a coated plate of glaſs; for that board which communicates with the earth will acquire an Electricity contrary to that of the other board; and if you touch them, *i. e.* make a communication between them, they will explode, give the ſhock, &c. ſimilar to a charged jar.

In this experiment it cannot be expected, that ſuch an exploſion, and with ſuch a force, will be produced, as by an equal ſurface of coated glaſs; for here the coatings cannot be brought ſo near one another as to render them capable of a high charge, becauſe the plate of air, being much leſs compact than glaſs, may be eaſily broken by the force of the charge, *i. e.* it may eaſily diſcharge itſelf. Notwithſtanding, however, that a plate of air is not capable of receiving a very high charge, yet this experiment has a great advantage, which is, that here we may ſee what preſſes between the two coatings, either in charging or diſcharging the plate of air; and we may introduce ſeveral things into the ſubſtance of this coated electric, which produce ſeveral remarkable appearances. By this experiment the true ſtate of the earth, when covered by electrified clouds, may be repreſented exceedingly well; and ſeveral meteors, that happen in that ſtate, and which are thought to be effects of Electricity, may be imitated; ſuch as waterſpouts and whirlwinds, beſides the well-known electrical phenomena, thunder and lightning.

In order to repreſent a water-ſpout, as it is often obſerved at ſea, place the two boards at about two inches diſtance from one another; put a large drop of water about the middle of the loweſt of them, and fix a metallic ball, or any other piece of metal that is ſomewhat ſpherical *, to the upper board, juſt oppoſite to, and at about half an inch diſtance from the ſurface of the water. If in this ſituation the upper board be electrified, whilſt the lower communicates with the earth, the water, which repreſents the ſea, will be attracted by the metallic ball, which repreſents a cloud, and riſing nearly in a conical body, will afford a pretty good repreſentation of the water-ſpout †.

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[*] The metallic covering of ſome kind of coat-buttons anſwers exceedingly well, and may be paſted on the tin-foil coating of the board.

[†] The knob of a charged bottle, being brought near the water in a metal plate, or common earthen-ware ſaucer, ſhows this experiment in a ſimple and beautiful manner. If a large drop of water be placed upon the knob of an inſulated charged bottle, and the knob of another bottle, charged with the contrary Electricity, be brought near the drop of water, it will be ſquirted

The appearance of a whirlwind is but ſeldom, and by chance to be obſerved. The bran between the two plates F, P, fig. 2, Plate I. is often whirled like the duſt in a whirlwind; but there is no certain rule, that I know, for producing this phenomenon.

In order to ſucceed in this experiment, Mr. BECKET directs to place the boards above-mentioned about four or five inches aſunder, and to put ſome bran, and very ſmall bits of paper about the center of the lower board. If in this ſituation the upper board be connected with the electrified prime Conductor, and the lower be either connected with the ground or with the rubber of the machine, the bran, and bits of paper will be attracted and repelled, alternately, by the boards. " But (ſays " Mr. BECKET *) the moſt ſurprizing ap- " pearance in this experiment, and what " gives it the moſt exact reſemblance of a " whirl-

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ſquirted away in a curious manner, particularly if the coating of the inſulated bottle be touched at the ſame time.

[*] In his Eſſay on Electricity, p. 141.

"whirlwind, is that ſometimes, when the "Electricity is very ſtrong, a quantity of "the paper and bran will accumulate in "one place, forming a kind of column "between the boards, and ſuddenly ac-"quire a ſwift horizontal motion, moving "like a whirling pillar to the edge of the "boards, and from thence fly off, and be "ſcattered about the room to a conſider-"able diſtance. I own I am entirely at a "loſs to account for this extraordinary ap-"pearance—I call it extraordinary, be-"cauſe it but ſeldom occurs, and ſeems to "depend either on a certain degree of at-"traction, quantity of the bran, or diſ-"tance between the boards; and I could "ſeldom get it to ſucceed perfectly but by "accident."

The phenomena of thunder and lightning are exhibited at the ſame time by a ſpontaneous diſcharge of the plate of air; which may be eaſily produced by ſetting the boards at about an inch diſtance from each other, and electrifying them ſtrongly.

EXPERIMENT

EXPERIMENT II.

To coat reſinous Electrics.

The beſt method to coat ſuch electrics as roſin, ſealing-wax, &c. that can eaſily be melted, is firſt to put a circular piece of tin-foil, about two inches leſs in diameter than the plate you intend to make, upon a marble table; then, to pour over it the electric juſt melted. This may be ſpread and flattened by preſſing it with a pane of glaſs, or any thing that is even and ſmooth; afterwards, another piece of tin-foil, equal to the former, is to be ſtuck upon the electric, which may be done by preſſing it gently with a hot iron; and then the plate, which may be eaſily ſeparated from the marble table, will be fit for uſe.

EXPERIMENT III.

To inſulate fluid Electrics.

Take a large earthen diſh, flat at the bottom, and ſtick within it a piece of tin-foil about an inch ſhorter than the flat part of the diſh all around, and through a ſmall hole, made in the bottom of the diſh, introduce a ſlender wire, which muſt communicate with the tin-foil; then pour into the diſh ſome melted tallow, or other electric ſubſtances that you deſire to try; laſtly, let a round braſs plate *, equal to the tin-foil ſtuck in the diſh, and either proceeding from a glaſs arm or from the prime Conductor, juſt touch the ſurface of the electric in the diſh, and let it ſtand parallel, and oppoſite to the tin-foil ſtuck in its bottom. In this manner the plate of liquid electric is coated, and may be eaſily ſubjected to experiments.

Plates of other conſiſtent electrics, that cannot eaſily be melted, may be coated in the ſame manner as a plate of glaſs; and ſome of them will be found to anſwer as well, if not better than glaſs.

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* The braſs plate F, fig. 2. of Plate I. may be very uſeful for this purpoſe.

CHAP. IX.

Experiments on the Influence of Points, and the Uſefulneſs of pointed metallic Conductors, to defend Buildings from the Effects of Lightning.

MY reader, in the courſe of this work, muſt have obſerved in ſeveral of the experiments already deſcribed, the remarkable property that points have, both of throwing off and receiving *ſilently* the electric fluid; but in this chapter I ſhall deſcribe ſome more curious experiments of this kind, by which the influence of points, in reſpect to Electricity, may be better underſtood, and which may, in a more particular manner, demonſtrate the utility of metallic Conductors to houſes, or piles of building, in order to preſerve them from the damage often occaſioned by a ſtroke of lightning; which is one of the greateſt benefits that mankind has received from the ſcience of Electricity.

EXPERIMENT I.

To diſcharge a Jar ſilently.

When a large jar is fully charged, which would give a terrible ſhock, put one of your hands in contact with its outſide coating; with the other hold a ſharp-pointed needle, and, keeping the point directed towards the knob of the jar, proceed gradually near it, until the point of the needle touches the knob. This operation diſcharges the jar entirely, and you will either receive no ſhock at all, or ſo ſmall a one as can hardly be perceived. The point of the needle, therefore, has ſilently and gradually drawn all the ſuperfluous fluid from the inſide ſurface of the electric jar.

EXPERIMENT II.

Drawing the Electricity from the prime Conductor by a Point.

Let a perſon hold the knob of a braſs rod at ſuch a diſtance from the prime

Conductor, that ſparks may eaſily fly from the latter to the former, when the machine is in motion. Then let the winch be turned, and, while the ſparks are following one another, preſent the ſharp point of a needle at nearly twice the diſtance from the prime Conductor, that the knobbed rod is held; and you will obſerve that no more ſparks will go to the rod;—remove the needle entirely, and the ſparks will be ſeen again; — preſent the needle, and the ſparks diſappear; which evidently ſhows, that the point of the needle draws off *ſilently* almoſt all the fluid that the cylinder throws upon the prime Conductor.

If the needle be fixed upon the prime Conductor with the point outward, and the knob of a diſcharging rod, or the knuckle of a finger, be brought very near the prime Conductor, though the excitation of the cylinder may be very ſtrong, yet you will perceive that no ſpark, or only an exceeding ſmall one, can be obtained from the prime Conductor.

EXPERIMENT III.

The electric Fly.

Fix the fly, deſcribed in the third chapter, upon the prime Conductor, as repreſented by D, fig. 2 of Plate I; then turn the winch of the machine, and the fly will immediately begin to move round in an horizontal poſition, and in the direction of the letters *a b c d*; *i. e.* contrary to the direction of the points of the wires. If the experiment is repeated with a Conductor negatively electrified, the fly will turn the ſame way as before, *viz.* in the direction of the letters *a b c d*. The reaſon of this experiment depends upon the repulſion exiſting between bodies poſſeſſed of the ſame Electricity; for whether the fly is electrified poſitively or negatively, the air oppoſite to the points of the wires (on account of the points eaſily tranſmitting Electricity) acquireth a ſtrong Electricity, analogous to that of the points; and therefore the air and the points muſt repel each other. This explanation is confirmed, by obſerving that the above fly not only does not move in vacuo; and even, if placed under a cloſe receiver, it will turn but for a little while, and then ſtop; for the quantity of air contained in the receiver, may become readily, and equally electrified *.

EXPERIMENT IV.

The electrified Cotton.

Take a ſmall lock of cotton, extended in every direction as much as conveniently can be done, and by a linen thread about five or ſix inches long, or by a thread drawn out of the ſame cotton, tie it to the end of the prime Conductor; then let the winch of the machine be turned, and the lock of cotton, on being electrified, will immediately ſwell, by repelling its filaments from one another, and will ſtretch itſelf towards the neareſt Conductor. In this ſituation, let the winch be kept turning, and preſent the end of your finger, or the knob of a wire, towards the lock of cotton, which will then immediately move towards the finger, and endeavour to touch it; but take with the other hand a pointed needle, and preſent its point towards the cotton, a little above the end of the finger, and you will obſerve the cotton immediately to ſhrink upward, and move towards the prime Conductor. Remove the needle, and the cotton will come again towards the finger. Preſent the needle, and the cotton will ſhrink again: which clearly ſhews, that the needle, being ſharp-pointed, draws off the electric fluid from the cotton, and puts it in a ſtate of being attracted by the prime Conductor; which could not be effected by a wire having a blunted end, or a round ball for its termination.

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* If, when the fly under the cloſe receiver is ſtopped, you put the end of a finger on the outſide of the glaſs, oppoſite to one of the points of the fly, this will move again briſkly; and by altering the poſition of your finger occaſionally round the glaſs, you may continue its action a conſiderable time, *viz.* till moſt of that part of the glaſs is charged. In this caſe, when the finger is applied on the outſide of the receiver, the glaſs loſing part of its natural electric fluid from the outſide (*i. e.* if the fly is electrified poſitively, or *vice verſa*, if negatively) receives the fluid of the electrified air on its inſide ſurface; hence this air is put in a ſtate of being again electrified by the point of the fly, which renews the motion of the fly.

EXPERIMENT V.

The electrified Bladder.

Take a large bladder, well blown, and cover it with gold, ſilver, or braſs leaf, ſticking it with gum-water; ſuſpend this bladder at the end of a ſilk thread, at leaſt ſix or ſeven feet long, hanging from the ceiling of the room, and electrify the bladder, by giving it a ſtrong ſpark with the knob of a charged bottle: this done, take a knobbed wire, and preſent it to the bladder when motionleſs, and you will perceive, that as the knob approaches the bladder, the bladder alſo moves towards the knob, and when nearly touching it, gives it the ſpark, which it received from the charged phial, and thus it becomes unelectrified. Give it another ſpark, and, inſtead of the knobbed wire, preſent the point of a needle towards it, and you will perceive that the bladder will not be attracted by, but rather recede from the point, eſpecially if the needle be very ſuddenly preſented towards it.—This is one of Mr. HENLY's experiments.

Before we proceed to the practical uſe of pointed Conductors to buildings, in order to defend them from lightning (which is nothing more than the proper application of the preceding experiments) it will be proper to ſay ſomething in explanation of the above property of points, which has lately occaſioned ſeveral controverſies. In order to this, it ſhould be remembered, that the electric fluid ſuperinduced upon an inſulated body, is confined upon that body by the air which ſurrounds it. Further, that Electricity, by being continually communicated to the air, which is never a perfect electric, is gradually diſſipated; from whence follows this very evident principle, *i. e.* that as a greater or leſs quantity of air is contiguous to a given quantity of electrified ſurface, ſo that ſurface loſeth its Electricity ſooner or later. Suppoſe, for inſtance, that a pointed needle is fixed upon the prime Conductor; mark a dot upon any part of the prime Conductor, which may be nearly equal to the point of the needle, and then electrify the prime Conductor. Now it is evident to bare inſpection, that although the point of the needle and the dot, &c. are of equal ſurfaces, yet the former is expoſed to a quantity of air, which almoſt entirely ſurrounds it, and which is vaſtly greater than the air contiguous to the latter: hence, the Electricity, communicated to the prime Conductor, is diſſipated more eaſily from the point of the needle than from the dot, or any other part of the prime Conductor. Beſides, the air about the point may more eaſily be moved, in conſequence of the electrical repulſion, than at any other part of the ſurface of the prime Conductor, and new air, *i. e.* unelectrified air, paſſes more frequently by it, which taking always part of the Electricity of that body, promotes alſo its diſſipation.

In the ſame manner may be underſtood, why the Electricity is more eaſily diſſipated at ſharp edges and corners, than at flat ones; for as the ſurfaces of bodies in general are more or leſs plain, ſo they are expoſed to a leſs or greater quantity of air, and participate more or leſs of the nature and properties of points.

When the pointed body is negatively electrified, it is for the ſame reaſon that it acquires the electric fluid through the point, eaſier than through any other part of its ſurface; *i. e.* becauſe the point exhibiting the leaſt ſurface to the greateſt quantity of free air, has the greateſt number of particles of air, from which it can extract the electric fluid *.

EXPERIMENT VI.

The Thunder-houſe.

Fig. 1. of Plate II. is an inſtrument repreſenting the ſide of a houſe, either furniſhed with a metallic Conductor, or not; by which both the bad effects of lightning ſtriking upon a houſe not properly ſecured, and the uſefulneſs of metallic Conductors,

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* For a more particular explanation of the abovementioned property of points, ſee BECCARIA's Artificial Electricity.

ductors, may be clearly repreſented. A is a board about three quarters of an inch thick, and ſhaped like the gable-end of a houſe. This board is fixed perpendicularly upon the bottom board B, upon which the perpendicular glaſs pillar C D is alſo fixed, in a hole about eight inches diſtant from the baſis of the board A. A ſquare hole, I L M K, about a quarter of an inch deep, and nearly one inch wide, is made in the board A, and is filled with a ſquare piece of wood, nearly of the ſame dimenſions. I mention nearly of the ſame dimenſions, becauſe it muſt go ſo eaſily into the hole, that it may drop off by the leaſt ſhaking of the inſtrument. A wire, L K, is faſtened diagonally to this ſquare piece of wood. Another wire, I H, of the ſame thickneſs, having a braſs ball, H, ſcrewed on its pointed extremity, is faſtened upon the board A; ſo alſo is the wire M N, which is ſhaped in a ring at O. From the upper extremity of the glaſs pillar C D, a crooked wire proceeds, having a ſpring ſocket F, through which a double-knobbed wire ſlips perpendicularly, the lower knob G of which falls juſt above the knob H. The glaſs pillar D C muſt not be made very faſt into the bottom board; but it muſt be fixed ſo as it may be pretty eaſily moved round its own axis, by which means the braſs ball G may be brought nearer or farther from the ball H, without touching the part E F G. Now when the ſquare piece of wood L M I K (which may repreſent the ſhutter of a window or the like) is fixed into the hole ſo, that the wire L K ſtands in the dotted repreſentation I M, then the metallic communication from H to O, is complete, and the inſtrument repreſents a houſe furniſhed with a proper metallic Conductor; but if the ſquare piece of wood L M I K is fixed ſo, that the wire L K ſtands in the direction L K, as repreſented in the figure, then the metallic Conductor H O, from the top of the houſe to its bottom, is interrupted at I M, in which caſe the houſe is not properly ſecured.

Fix the piece of wood L M I K, ſo that its wire may be as repreſented in the figure, in which caſe the metallic Conductor H O is diſcontinued. Let the ball G be fixed at about half an inch perpendicular diſtance from the ball H, then, by turning the glaſs pillar D C, remove the former ball from the latter: by a wire or chain connect the wire E F with the wire Q of the jar P, and let another wire or chain, faſtened to the hook O, touch the outſide coating of the jar. Connect the wire Q with the prime Conductor, and charge the jar; then, by turning the glaſs pillar D C, let the ball G come gradually near the ball H, and when they are arrived ſufficiently near one another, you will obſerve that the jar explodes, and the piece of wood, L M I K, is puſhed out of the hole to a conſiderable diſtance from the thunder-houſe. Now the ball G, in this experiment, repreſents an electrified cloud; which, when it is arrived ſufficiently near the top of the houſe A, the Electricity ſtrikes it, and, as this houſe is not ſecured with a proper Conductor, the exploſion breaks part of it, *i. e.* knocks off the piece of wood I M.

Repeat the experiment with only this variation, *viz.* that this piece of wood I M is ſituated ſo, that the wire L K may ſtand in the ſituation I M; in which caſe the Conductor H O is not diſcontinued; and you will obſerve, that the exploſion will have no effect upon the piece of wood L M; this remaining in the hole unmoved; which ſhows the uſefulneſs of the metallic Conductor.

Further: Unſcrew the braſs ball H from the wire H I, ſo that this may remain pointed, and, with this difference only in the apparatus, repeat both the above experiments; and you will find that the piece of wood I M is in neither caſe moved from its place, nor any exploſion will be heard; which not only demonſtrates the preference of Conductors with pointed terminations to thoſe with blunted ones, but alſo ſhows, that a houſe furniſhed with ſharp terminations, although not furniſhed with a regular Conductor, is almoſt ſufficiently guarded againſt the effects of lightning.

To prove farther the preference of pointed Conductors to blunt ones, the experiment of the electrified cotton (*viz.* the fourth experiment of this chapter) may be eaſily repeated with this apparatus; by which it may be ſhown, that a pointed Conductor ſilently drawing off the electric fluid from the ſmall clouds near it, which are repreſented by the cotton tied to the wire of the ball G, repels them, and may thus, in ſome caſes, perhaps, actually prevent a ſtroke of lightning; whereas the blunted Conductor facilitates it. Small feathers may alſo be tied near the knob G, which, by repelling one another, may exhibit a better repreſentation of an electrified cloud; and in ſhort, with a little contrivance, the above-deſcribed apparatus, commonly called the *Thunder-houſe*, may be adapted to repreſent the principal phenomena of lightning, together with ſeveral circumſtances preceding, or following it.

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CHAP. X.

The practical Adminiſtration of Medical Electricity.

WHEN we mentioned the uſes of Electricity, in the Firſt Part of this Treatiſe, we obſerved that Electricity had been found beneficial in many diſorders, occaſioned by obſtructions, in which a promotion of the inſenſible perſpiration, and of glandular ſecretion, was neceſſary, or an additional impetus required to be given to the common courſe of the fluids in the human body. We alſo conſidered the different opinions relating to this ſubject. In this chapter, therefore, nothing remains but to deſcribe a practical method of applying Electricity to the human body, when affected with different diſtempers.

With reſpect to the electrical machine in general, I ſhall only obſerve, that its ſize ſhould not be ſo ſmall as was thought ſufficient ſome time ago, when the ſmalleſt machines were ſuppoſed to be ſufficiently uſeful for the purpoſe. It is ſomewhat remarkable, that when a ſmall power of Electricity is to be uſed, large machines ſhould be recommended; whereas, a ſhort time ago, ſtrong ſhocks were adminiſtered, and ſmall electrical machines were uſed; but it muſt be conſidered, that when ſhocks are given, very ſmall electrical machines can charge a Leyden phial much ſtronger than required; but when the ſtream is uſed, which has lately been found to be far more efficacious; then the ſmall machines are moſtly uſeleſs. Probably the largeſt machines will not be found to afford a ſtream too ſtrong for medical purpoſes; but the uſeful ones, which do not require a great labour to be put in motion, and may furniſh a ſufficiently denſe ſtream, ſhould have the glaſs globe, or cylinder, at leaſt nine inches in diameter; which, with a proportionate conductor, may uſually give ſparks about three inches long. Whether the rubber of theſe machines ſtands upon a glaſs pillar or not; *viz.* whether it may be occaſionally inſulated or not, ſeems to be immaterial with reſpect to medical Electricity: but as to have it ſituated upon a glaſs pillar, is uſeful for electrical experiments in general; and perhaps it may be found hereafter, that negative electrization is beneficial in ſome diſorders, a perſon who is to chooſe a new electrical machine, may rather have the rubber fixed upon a glaſs pillar, than otherwiſe.

With ſuch machines, the power of Electricity ſhould be ſo regulated, as to apply every degree of it with facility and readineſs; beginning with a ſtream iſſuing out of a metal point, next uſing a wooden point, then ſmall ſparks, ſtronger ſparks, and laſtly, ſmall ſhocks. Every one of theſe methods may be increaſed or diminiſhed conſiderably, by a proper management: thus, by turning the wheel of the machine ſwifter or ſlower, the ſtream of electric fluid may be regulated according as the circumſtances may require. The ſparks may alſo be made ſtronger or weaker, by taking them at a greater or leſs diſtance, and by turning the wheel ſwifter or ſlower; and ſo of the reſt.

It is impoſſible to preſcribe the exact degree of electrization that muſt be uſed for various diſorders; for perſons of different conſtitutions, although afflicted with the very ſame diſeaſe, require different degrees of electrization. Some perſons are of ſo delicate and irritable conſtitution, that the ſmalleſt ſparks give them as much pain as ſhocks do to others. On the contrary, ſome people can ſuffer pretty ſevere ſhocks without poſitive pain; and I have heard, though never ſaw any, of perſons who were inſenſible of any electric power, even of conſiderably ſtrong ſhocks.

In reſpect to this important point, the operator muſt be certainly inſtructed by experience; however, in the beginning, he may be aſſiſted by the two following rules: Firſt, he ſhould begin to adminiſter to his patients the very ſmalleſt degree of electric power, which he ought to continue for a few days, ſo as to obſerve whether it produces any good effect, which if it fails to do, he ſhould then increaſe the ſtrength of electricity; and ſo proceed gradually till he finds the effectual method, which he ſhould follow without variation, till the patient is intirely cured. In ſhort, the operator ſhould always uſe the ſmalleſt degree of electric power, that is ſufficient for the purpoſe. A little practice will enable him to determine at once what degree of Electricity is required for his patient, without any uſeleſs attempts. Secondly, the degree of electrization to be adminiſtered, ſhould never exceed that, which the patient can conveniently ſuffer; experience ſhewing, that when the application of any degree of Electricity is very diſagreeable to the patients, they very ſeldom mend.

The inſtruments which, beſides the electrical machine and its prime Conductor, are neceſſary for the adminiſtration of medical Electricity, may be reduced to three; *viz.* an electric jar, with Mr. LANE's electrometer; an inſulated chair, or an inſulated ſtool, upon which a common chair may be occaſionally ſet; and the *directors* *.

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* Various other inſtruments uſeful in medical Electricity, are deſcribed in divers books, but thoſe mentioned above are ſufficient to anſwer every required purpoſe.

As for the jar with Mr. LANE's electrometer, it has been already deſcribed, and is clearly ſhewn by fig. 6. of Plate II. We may only obſerve, that for medical Electricity this jar needs not be large; it being fully ſufficient when it contains about 60 or 70 ſquare inches of coated ſurface. The balls A B of the electrometer, at moſt ſhould not be placed farther aſunder than a quarter of an inch, but in general one tenth of an inch diſtance is ſufficient.

When the ſhocks are to be given with this apparatus to any particular part of the body, for inſtance, to the arm, then, inſtead of the dotted line repreſenting a wire, which muſt now be ſuppoſed as not exiſting in the figure, two ſlender and pliable wires, C H, K I, are to be faſtened, one to the open ring C of the electrometer, and the other to the outſide coating of the jar. The other extremities of the ſaid wires are faſtened each to the braſs wire I, and H of the directors I L, H L. Each of thoſe inſtruments, juſtly called *directors*, conſiſts of a knobbed braſs wire, which by means of a braſs cap is cemented to the glaſs handle L. The operator holding them by the extremity of the glaſs handle, brings their balls into contact with the extremities of that part of the body of the patient, through which he deſires to ſend the ſhock. The management and convenience of this apparatus are eaſily comprehended; for when the machine is in motion, and the apparatus, &c. is ſituated as in the figure, the diſcharge of the jar muſt be evidently made through that part of the patient which lies between the knobs of the directors; and the operator, whilſt an aſſiſtant keeps the machine in motion, has nothing more to do, but to hold the knobs of the directors to the extremities of the arm, or to any other part of the body that is required to be thus electrified; always taking care that the two wires K I, C H, do not touch each other, becauſe in that caſe the ſhock will not paſs through that part of the body which is required to be electrified. Thus any number of ſhocks, preciſely of the ſame ſtrength, may be given, without altering any part of the apparatus, or having any farther trouble; and when the ſtrength of the ſhocks is required to be diminiſhed or increaſed, it is only neceſſary to diminiſh or augment the diſtance between the balls B C, which is done by ſlipping the wire C B forwards or backwards through the ſpring ſocket that holds it.

It is almoſt ſuperfluous to mention, that when ſhocks are adminiſtered, it is immaterial whether the patient ſtands upon the ground, upon the inſulating ſtool, or in any other ſituation whatever. It is neither always neceſſary to remove the cloaths from the part that muſt be electrified, in order to let the knobs of the directors touch the ſkin; for except the coverings be too many and too thick, in which caſe part of them at leaſt ſhould be removed, the ſhocks will go through them very eaſily, eſpecially if the knobs of the directors be preſſed a little upon the part.

Beſides the directors mentioned above, there are other kinds of directors, which ſerve for throwing the ſtream of electric fluid, and other ſimilar purpoſes. Theſe are much like thoſe deſcribed above, excepting only that its wire is bent, and inſtead of having any ball, it terminates in a point, to which is affixed a piece of wood about one inch or one inch and a half long, pointed at one end, though not very ſharp, and having a hole at the other. The operator should have by him various ſuch wooden pieces, of different length and thickneſs, ſo as to ſhift them according as circumſtances may require; for ſometimes the wooden pieces are too dry or too damp, or the machine is in bad order, &c. in which caſes the ſtream of electric fluid would be either too ſtrong or too weak, if the ſame wooden point was always uſed. The wood proper to make theſe pointed pieces ſhould be rather of a ſoft kind, than hard, as box wood and lignum vitæ are.

In order to throw the electric fluid with this director, let a wire proceeding from the prime Conductor be faſtened to the wire of the director, which the operator muſt hold by the extremity of the glaſs handle, and muſt manage it ſo as to keep the wooden point at about one or two inches diſtance from the body of the patient.

tient*. This diſtance, however, muſt be regulated according to the conſtitution of the patient, the ſtrength of the electrical machine, and other circumſtances; which will be ſuggeſted by a little practice. The electric fluid iſſuing from the wooden point, has a power which is intermediate between that of the ſtream proceeding from a metal point, and the power of the ſparks; but yet it is in general the moſt efficacious method of electrization, and therefore no pains ſhould be ſpared in order to adminiſter it in the beſt poſſible manner. This ſtream conſiſts of a vaſt number of exceedingly ſmall ſparks, accompanied with a little wind, which gently irritates the part electrified, and gives a warmth which proves very agreeable to the patients. Sometimes, when the machine is very powerful, and the wooden point is ſhort or ſplit, a very full and pungent ſpark iſſues from it, which is a very diſagreeable accident,

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[*] When this or any other operation is performed, the electric jar, and in general any inſtrument not actually neceſſary, muſt be removed from the prime conductor, and even from the table if that is rather ſmall.

dent, eſpecially when the part electrified is very delicate. In order to avoid this inconvenience, the operator ſhould firſt try the goodneſs of the point, before he begins the operation; which he may do by throwing the ſtream upon his own hand or face.

The above-mentioned method of electrifying, gentle as it may appear, will nevertheleſs be found too ſtrong for ſome perſons, eſpecially when uſed for open ſores upon delicate parts; in which caſes the wooden point muſt be removed, and the electric fluid muſt be ſimply thrown from the metal point of the director, which muſt now be kept at a greater diſtance than when the wooden piece was upon it. The electric fluid iſſuing out of this pointed wire of the director, occaſions only a gentle wind upon the part towards which it is directed, and is far from being diſagreeable even to the moſt delicate conſtitution.

It might be naturally ſuſpected, that ſo gentle and nearly inſenſible a treatment could hardly be of any efficacy; but my reader may be aſſured, that to my certain knowledge, deduced from the practice of perſons who have had long experience in this ſubject, this method of electrization, *viz.* the throwing the fluid with a metal point, has often mitigated pains, and cured obſtinate and dangerous diſeaſes, which could not be removed by any other remedy that was tried.

In general, this treatment upon delicate nervous conſtitutions, is as efficacious as the other, *viz.* the throwing the fluid with a wooden point, is to ordinary conſtitutions. In ſeveral caſes, eſpecially of open ſores, the electric fluid iſſuing out of a wooden point has conſtantly increaſed the pain, and even enlarged the ſore; whereas the fluid iſſuing out of the metal point, has effectually diminiſhed both.

The ſtream iſſuing out of a wooden point may be directed towards the eyes of the patient, without any apprehenſion of hurting him; in which caſe the operator ſhould keep the eye-lid open with one hand. Indeed there may be ſome caſes, though

I ſeldom heard of any, in which this treatment may be thought to be too ſtrong; then the metal point only may be uſed.

The ſtream iſſuing both out of the wooden and of the metal point, acts even through the cloaths, if they are not too thick; hence it may be uſed without incommoding the patient; but when it is convenient to uncover the part that is to be electrified, it is much preferable to direct the fluid immediately upon the ſkin.

In this operation, the practitioner muſt mind to ſhift the point of the director about, ſo that the ſtream of electric fluid may be directed not only towards the affected part, but alſo to the places about it; alternately returning to the ſame place, and moſtly inſiſting upon the part principally affected.

The patient in this operation may alſo ſtand in every ſituation that may happen to be more convenient to him.

When more proper inſtruments cannot be had, directors may be made by ſticking large pins upon ſticks of ſealing-wax.

In regard to the continuation of the operation in various caſes, it is impoſſible to give any particular directions, ſince the variety of caſes is almoſt infinite. The operator will be eaſily inſtructed by practice; but for the beginning he may obſerve, that when ſparks are adminiſtered, a dozen of them is fully ſufficient; but when the ſtream of electric fluid is uſed, the operation may be continued for about 3 or 4 minutes per day. — As for farther particulars relating to the ſubject of this chapter, I muſt refer my reader to my Eſſay on medical Electricity; the limits of this work not permitting me to inſiſt longer upon it.

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CHAP. XI.

Experiments with the electrical Battery.

THE force of accumulated Electricity, great as it appears by the experiments performed with a ſingle coated jar, is very ſmall when compared with that, which is produced by a number of jars connected together; and if the effects of a ſingle jar are ſurpriſing, the prodigious force of a large battery is certainly aſtoniſhing. To obſerve that the metals, even the moſt purified platina, which reſiſts the greateſt efforts of chemic fire, are actually, and almoſt inſtantaneouſly rendered red-hot, and fuſed; to ſee animals deſtroyed; and to hear the loud report of a large electric battery, are things that always produce a kind of terror in the mind of an attentive obſerver. Experiments of this kind ſhould be conducted with great caution, and the Operator ought to be attentive, not only to the buſineſs in hand, but alſo to the perſons who may happen to be near him, prohibiting their touching, or even coming too near any part of the apparatus; for if a miſtake in performing other experiments may be diſagreeable, thoſe in the diſcharge of a large battery may be attended with worſe conſequences.

When a battery is to be charged, inſtead of a large prime Conductor, a ſmall one is much more convenient; for, in this caſe, the diſſipation of the Electricity is not ſo conſiderable. The quadrant electrometer, which ſhows the height of the charge in the battery, may be fixed either upon the prime Conductor, or upon the battery; in which latter caſe, it ſhould be placed upon a rod proceeding from the wires of the jars, and if the battery be very large, it ſhould be elevated two or three feet above them.

The index of the electrometer in charging a large battery will ſeldom riſe ſo high as 90°, becauſe the machine cannot charge a battery ſo high in proportion, as a ſingle jar. Its limit is often about 60° or 70°, more or leſs in proportion to the ſize of the battery, and the force of the machine.

EXPERIMENT I.

To melt Wires.

Connect with the hook, communicating with the outſide coating of a battery, containing at leaſt thirty ſquare feet of coated ſurface, a wire, that is about one fiftieth part of an inch thick, and about two feet long; the other end of it muſt be faſtened to one end of the diſcharging rod; this done, charge the battery, and then, by bringing the diſcharging rod near its wires, ſend the exploſion through the ſmall wire, which, by this means, will be made red-hot, and melted, ſo as to fall upon the floor in different glowing pieces. When a wire is melted in this manner, ſparks are frequently ſeen at a conſiderable diſtance from it, which are red-hot particles of the metal, that by the violence of the exploſion are ſcattered in all directions. If the force of the battery is very great, the wire will be intirely diſperſed by the exploſion, ſo that none of it can be afterwards found.

By repeating this experiment with wires of different metals, and the ſame force of exploſion, it will be found that ſome metals are more readily fuſed than others, and ſome not at all affected; which ſhows the difference of their conducting power. If it be required to melt ſuch particles of metals, that cannot eaſily be drawn in wires, as ores, grain gold, &c. they may be ſet in a train upon a piece of wax; this train may be inſerted in the circuit, and an exploſion may be ſent through it, which, if it is ſufficiently ſtrong, will melt the metallic particles, as well as the wires: or, if the quantity to be tried be large enough, it may be confined in a ſmall tube of glaſs.

In melting wires of a conſiderable length, it is often obſerved, that when the force of the exploſion is juſt ſufficient to render the wire red-hot, the redneſs begins firſt from one end of it, namely, that which communicates with the poſitive ſide of the battery, and from thence gradually proceeds to the other end. This is another ocular demonſtration of the theory of a ſingle electric fluid. Indeed the wire is not rendered red-hot in one place before the other, becauſe the electric fluid paſſes firſt through the former, and then through the latter, for that difference of time is by far too ſmall to be obſerved; but, becauſe the electric fluid loſes ſome of its impetus, or velocity, in going through the wire; hence the part of the wire which the electric fluid enters, ſuffers the greateſt effect of the ſhock, and, conſequently, becomes red ſooner, and in a greater degree.

If a wire is ſtretched by weights, and a ſhock is ſent through it, which renders it juſt red-hot, the wire, after the exploſion, will be found conſiderably lengthened; but if the wire is left looſe, after a ſimilar exploſion it will be found ſhortened*. If a wire is melted upon a piece of glaſs, the glaſs, after the exploſion, will be found marked with all the priſmatic colours.

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* This is a late obſervation of Mr. EDWARD NAIRNE. See the Phil. Tranſ. vol. LXX.

EXPERIMENT II.

To ſhow that the electric Fluid prefers a ſhort Paſſage through the Air, to a long one through good Conductors.

Bend a wire about five feet long in the form repreſented by fig. 11. Plate II. ſo that the parts A B may come within half an inch of one another; then connect the extremities of the wire with the hook of the battery, and the diſcharging-rod, as directed in the preceding experiment, and ſend the charge of a battery through it. On making the exploſion, a ſpark will be ſeen between A and B, which ſhows that the electric fluid chooſes rather a ſhort paſſage through the air, than the long one through the wire. The charge, however, does not paſs intirely through A and B, but part of it goes alſo through the wire; which may be proved by putting a ſlender wire between A and B; for, on making the diſcharge with only this addition in the apparatus, the ſmall wire will be hardly made red-hot; whereas, if the large wire A D B be cut in D, ſo as to diſcontinue the circuit A D B, the ſmall wire will be melted, and even exploded, by the ſame ſhock that before made it ſcarcely red-hot. In this manner (ſays Dr. PRIESTLEY, who is the inventor of this experiment) may the conducting power of different metals be tried, uſing metallic circuits of the ſame length and thickneſs, and obſerving the difference of the paſſage through the air in each.

EXPERIMENT III.

To make Globules of Metals.

Take a very ſlender wire, and put it in a glaſs tube, about one quarter of an inch in diameter; then ſend the charge of a battery through it, and the wire will be melted, and reduced into globules of different ſizes, which are found ſticking on the inſide ſurface of the glaſs tube, and they may be eaſily ſeparated from it at pleaſure: theſe, upon examination, will all be found hollow, and are little more than a mere ſcoria of metal.

It muſt be obſerved, in making this experiment, that the charge of the battery muſt neither be too high nor too weak; for in the former caſe, the wire will be reduced into pieces exceedingly ſmall, or rather exploded in ſmoke; and in the latter caſe, it will be imperfectly fuſed, ſo that its pieces will be large and irregular.

EXPERIMENT IV.

The Fairy Circles.

Fix upon each of the knobs D D of the univerſal diſcharger, fig. 5. Plate I. or upon the wires that ſupport the knobs, if the knobs are removed, a flattiſh and ſmooth piece of metal, or ſemi-metal (watch-caſes are very fit for this purpoſe) ſo that their ſurfaces may come ſo near each other, that the battery may be diſcharged through them; then connect one wire of the diſcharger with the outſide of the battery, and the other wire, by the help of the diſcharging rod, with the inſide of it, ſo as to make the diſcharge; which will occaſion the ſpot and circles deſcribed in the firſt part of this Treatiſe, upon the ſurface of each of the pieces of metal fixed upon the diſcharger.

Theſe circles have hitherto been exhibited upon the ſurface of no other ſubſtances but metals; and they are found to be marked more diſtinctly upon ſuch metals as melt with the leaſt heat. The moſt beautiful of theſe rings are produced by a number of diſcharges from a large battery, every part of the apparatus remaining exactly in the ſame ſituation. If the pieces of metal receive the exploſion in vacuo, the ſpot formed on them is very irregular and confuſed.

I have given theſe ſpots the appellation of *Fairy Circles*, on account that they bear ſome reſemblance to the ſpots ſo called, which are often obſerved upon the graſs in the fields. Theſe, which we may call natural Fairy Circles in the fields, have been thought to be effected by lightning, on account of their bearing ſome reſemblance to the above-mentioned circles produced by Electricity; the ſuppoſition,

however,

however, ſeems not very probable; for the ſpots in the fields, called Fairy Circles, have no central ſpot, no concentric circles, neither are they always of a circular figure; and, as I am informed, they ſeem to be rather beds of muſhrooms than the effects of lightning.

EXPERIMENT V.

To mark coloured Rings on Metals.

In order to exhibit coloured rings upon the ſurface of metals, place a plain piece of any of the metals upon one of the wires of the univerſal diſcharger, and upon the other wire fix a ſharp-pointed needle, with the point juſt oppoſite to the ſurface of the metal; then connect one wire of the diſcharger with the outſide of a battery, and the other with the diſcharging-rod, &c. In this manner, if exploſions are repeatedly ſent either from the point to the piece of metal, or from the latter to the former, they will gradually mark the ſurface of the piece of metal oppoſite to the point with circles, conſiſting of all the priſmatic colours; which are evidently occaſioned by laminæ of the metal, raiſed by the force of the exploſions.

Theſe colours appear ſooner, and the rings are cloſer to one another, when the point is nearer to the ſurface of the metal. The number of rings is greater or leſs, according as the point of the needle is more ſharp or more blunt; and they are repreſented equally well upon any of the metals.

The point of the needle is alſo coloured to a conſiderable diſtance; the colours upon it returning in circles, though not very diſtinctly. This is an experiment of Dr. PRIESTLEY.

EXPERIMENT VI.

The imitation of an Earthquake.

The appearance of the earthquake, as repreſented with the exploſion of a battery, is occaſioned by the concuſſion given to ſeveral ſubſtances by the exploſion paſſing over their ſurfaces. To give a repreſentation of the impreſſion made upon houſes by the earthquake, ſmall ſticks, cards, or the like, may be placed upon the ſurface of the body over which the exploſion is to be tranſmitted, ſo as to ſtand very light. Theſe ſticks, &c. will never fail to be ſhook, and often be thrown down by the exploſion.

It is remarkable, that an exploſion will not paſs over the ſame length of ſurface of all bodies, though they are equally good Conductors. Water, ice, wet wood, raw fleſh, and moſt of the animal fluids, are the beſt to make this remarkable experiment; to do which, nothing more is required than to inſert part of the ſurface of the ſaid ſubſtances into the circuit of the two ſides of a battery; a chain, for inſtance, communicating with the outſide, may be placed ſo as nearly to touch the ſurface of a quantity of water, and at about eight or nine inches diſtant * from another

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* The diſtance at which an exploſion will ſtrike over the ſurface of the above-mentioned ſubſtances, is much greater than that it can ſtrike through in air only.

chain, ſituated alſo very near the ſurface of the water, and communicating with one end of the diſcharging-rod. If the ends of the chains touch the water, the experiment will happen in the ſame manner.

The report, in this experiment, is much louder than when the exploſion paſſes through the air only. The concuſſion given to the water, by the exploſion paſſing over its ſurface, is not only ſuperficial, but affects its whole body; and if the hand is kept deep under its ſurface whilſt the exploſion paſſes over it, the concuſſion may be very ſenſibly felt.

The ſpark, that in this experiment paſſes over the ſurface of the water, ſeems to bear a great reſemblance to the balls of fire that have ſometimes been ſeen over the ſurface of the ſea or land in time of an earthquake; and hence it ſeems very probable, that thoſe balls of fire are electrical phenomena.

CHAP. XII.

Promiſcuous Experiments.

EXPERIMENT I.

To ſhow that Smoke, and the Vapour of hot Water, are Conductors.

LET a cork-ball electrometer be ſuſpended about four or five feet above the prime Conductor, then turn the winch of the machine very gently, and you will find, that the balls of the electrometer will not diverge. Put upon the prime Conductor a wax-taper * juſt blown out, ſo that its ſmoke may aſcend to the electrometer; then turn the winch again, and the balls of the electrometer will immediately ſeparate a little, with the ſame force of Electricity, from the prime Conductor; which ſhows that ſmoke is a Conductor in a ſmall degree.

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* A green wax-taper is the beſt for this experiment.

In the ſame manner, by placing a ſmall veſſel with hot water upon the prime Conductor, inſtead of the wax-taper, it may be proved, that its vapour is alſo a Conductor; but inferior in its conducting power to the ſmoke. This experiment is an invention of Mr. HENLY.

EXPERIMENT II.

To prove that Glaſs, and other Electrics, become Conductors, when they are made very hot.

Take a ſmall glaſs tube of about one twentieth of an inch in diameter, and above a foot long; cloſe it at one end, and introduce a wire into it, ſo that it may be extended through its whole length: let two or three inches of this wire project above the open end of the tube, and there faſten it with a bit of cork; tie round the cloſed end of the tube another wire, which will be ſeparated from the wire within the tube only by the glaſs interpoſed between them. In theſe circumſtances endeavour to ſend a ſhock through the two wires;

i. e. the wire inſerted in the glaſs tube, and that tied on its outſide, by connecting one of them with the outſide, and touching the other with the knob of a charged jar, and you will find that the diſcharge cannot be made, unleſs the tube be broken; becauſe the circuit is interrupted by the glaſs at the end of the tube which is interpoſed between the two wires. But put that end of the tube to which the wire is tied into the fire, ſo that it may become juſt red-hot, then endeavour to diſcharge the jar again through the wires, and you will find that the exploſion will be eaſily tranſmitted from wire to wire, through the ſubſtance of the glaſs, which, by being made red-hot, is become a Conductor.

In order to aſcertain the conducting quality of hot reſinous ſubſtances, oils, &c. bend a glaſs tube in the form of an arch C E F D, fig. 7. Plate II. and tie a ſilk ſtring G C D to it, which ſerves to hold it by when it is to be ſet near the fire; fill the middle part of this tube with roſin, ſealing-wax, &c. then introduce two wires A E, B F through its ends, ſo that they may touch the roſin, or penetrate a little way in it. This done, let a perſon hold the tube over a clear fire, ſo as to melt the roſin within it; at the ſame time, by connecting one of the wires, A or B, with the outſide of a charged jar, and touching the other with the knob of the jar, endeavour to make the diſcharge through the roſin, and you will obſerve that, while the roſin is cold, no ſhocks can be tranſmitted through it; but it becomes a Conductor according as it melts, and when totally melted, the ſhocks will paſs through it very freely.

EXPERIMENT III.

To ſhow that hot Air is a Conductor.

Electrify one of the cork-ball electrometers, ſuſpended upon the ſtand, fig. 4. of Plate I. or electrify the prime Conductor with the quadrant electrometer; then bring a red-hot iron within a ſufficient diſtance of the electrometer, or prime Conductor, and you will find that they ſoon loſe their Electricity, which is certainly conducted by the hot air contiguous to the iron; for if the experiment be repeated with the ſame iron when cold, *i. e.* by bringing it within the ſame diſtance of the electrified Electrometer, or prime Conductor, their Electricity will not be conducted away as before *.

The above experiments may reaſonably induce us to ſuſpect, that ſeveral ſubſtances which are ranged among Conductors, would become Electrics, if they were brought into a cold temperature; and that all the Electrics become Conductors, when they are heated in a very high degree.

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* It has been often obſerved, that a battery may be diſcharged, by introducing a red-hot iron between two knobs interpoſed, and ſtanding at ſome diſtance from each other in the circuit; but if, inſtead of iron, there be introduced a piece of red-hot glaſs between the knobs (the diſtance between them remaining as at firſt) the battery cannot be diſcharged: whence we may infer, that either hot air is not ſo good a Conductor as has been imagined, or elſe, that air heated by iron (perhaps from its ignited particles) is ſtronger, with reſpect to its conducting power, than when heated by the red-hot glaſs.

EXPERIMENT IV.

To electrify the Air of a Room.

The air ſurrounding the electrical machine when in uſe, and contiguous to every highly-electrified body, always acquires a portion of Electricity, which it retains for a conſiderable time, and which, in ſome meaſure, counteracts the Electricity of electrified bodies *. A very expeditious method, however, to electrify the air, is to fix two or three needles upon the prime Conductor, and to keep it ſtrongly electrified for about ten minutes. If afterwards an electrometer be brought into the air ſurrounding the apparatus, it will plainly ſhow, that the air has acquired a conſiderable quantity of Electricity, which it will retain even after the apparatus has been removed into another room. To electrify the air negatively, connect the pointed needles with the rubber when inſulated; and make a communication by a chain, or wire, from the prime Conductor to the table.

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* An electrometer ſuſpended to the prime Conductor, will diverge moſt after a few turns of the wheel; but afterwards the divergence will leſſen, according as the air about the apparatus becomes electrified.

Another method of electrifying the air is, to charge a large jar, and inſulate it: then connect a ſharp-pointed wire, or a number of them, with the knob of the jar; and make a communication from the outſide coating to the table. If the jar be charged poſitively, the air of the room will ſoon become ſtrongly electrified poſitively likewiſe; but if the jar be charged negatively, the air will become alſo negative. A charged jar being held in one hand, and the flame of a candle, inſulated, and held in the other, being brought near the knob of the jar, will alſo ſoon produce the ſame effect.

EXPERIMENT V.

The Atmoſphere of Smoke.

Take a braſs ball, or any piece of metal that is free from points or edges, of about three or four inches diameter, and inſulate it upon a narrow electric ſtand; then give it a ſpark with the knob of a charged phial, and immediately preſent to it a wax-taper juſt blown out and ſmoking. The ſmoke, in this caſe, will be attracted by the electrified body, and, by encompaſſing that body, will form a kind of atmoſphere about it. This atmoſphere will remain for a few ſeconds, and afterwards, beginning from the bottom, will gradually vaniſh, until at laſt, entirely departing from the electrified body, it goes off in a ſlender column, that ſoon rarefies, and diffuſes itſelf into a conſiderable ſpace.

This experiment will not ſucceed, unleſs it be made in very dry weather, and in a room where the air is not agitated. Care muſt alſo be taken, that, in blowing out the taper, and preſenting it to the electrified body, the air be diſturbed as little as poſſible.

This phenomenon has induced ſome philoſophers to ſuppoſe, that the Electricity of an electrified body reſided about it, *i. e.* reſted upon its ſurface like an atmoſphere; which, they thought, was made very evident by the ſmoke. But this appearance, when duly conſidered, is far from proving any ſuch electric atmoſphere; and the cauſe of it may be very eaſily explained in the following manner:—The ſmoke is attracted by the electrified body in the ſame manner, and for the ſame reaſon, that other bodies are attracted by it. It remains ſuſpended about that body, and cannot all come into contact with its ſurface, on account of the elaſticity of its particles. It remains ſo long ſuſpended about the electrified body, and is not immediately repelled, becauſe it is a bad Conductor, and acquires Electricity very ſlowly; but, having acquired a ſufficient quantity of Electricity, it begins to quit the electrified body, and, aſcending in the air, extends itſelf into a large ſpace, in conſequence of the repulſion exiſting between its own electrified particles.

EXPERIMENT VI.

To ſhew that Metals conduct the electric Fluid through their Subſtance.

Take a wire of any kind of metal, and cover part of it with ſome electric ſubſtance, as roſin, ſealing-wax, &c. then diſcharge a jar through it, and it will be found, that it conducts as well with as without the electric coating. This proves that the electric fluid paſſes through the ſubſtance of the metal, and not over its ſurface. A wire continued through a vacuum, is alſo a convincing proof of the truth of this obſervation.

EXPERIMENT VII.

The electrified Cup and Chain.

Inſulate a metallic cup, or any other concave piece of metal, and place within it a pretty long metallic chain, having a ſilk thread tied to one of its ends. To the handle of the cup, or to a wire proceeding from it, ſuſpend a cork-ball electrometer; then electrify the cup, by giving it a ſpark with the knob of a charged phial, and the balls of the electrometer will immediately diverge. If, in this ſituation, one end of the chain be gradually raiſed up above the top of the cup, &c. by the ſilk thread, while the lower end of the chain remains in it, the balls of the electrometer will converge a little, and more or leſs in proportion to the elevation of the chain above the top of the veſſel; which proves that the Electricity of the cup and chain together is more denſe when theſe bodies are in a compact, than when they are in a more extended form. A more eaſy method to ſhew this property of Electricity, is that uſed by T. RONAYNE, Eſq; which is as follows: — He excites a long ſlip of white flannel, or a ſilk ribband, by rubbing it with his fingers; then, by applying his hand to it, takes off as many ſparks as the excited electric will give; but when the flannel, &c. has loſt the power of giving any more ſparks in this manner, he doubles, or rolls it up; by which operation the contracted flannel, &c. appears ſo ſtrongly electrical, that it not only gives ſparks to the hand brought near, but it throws out ſpontaneous bruſhes of light, which appear very beautiful in the dark.

EXPERIMENT VIII.

To ſhow the Courſe of the electric Fluid by the Flame of a Wax-taper.

Fix at that extremity of the prime Conductor which is the remoteſt from the machine, a braſs rod ſix inches long, having on its extremity a braſs ball about three-fourths of an inch in diameter, and let the winch of the machine be moved.

If in this ſituation the flame of a wax-taper be preſented to the above-mentioned braſs ball, it will be blown almoſt horizontally, and in a direction from the ball; that is, in the direction of the electric fluid. If a wire, with a like ball, be fixed to the inſulated rubber, the flame of a wax-taper, preſented to this ball, will be blown alſo in the direction of the electric fluid; that is, it will be blown upon the ball, ſhowing the true courſe of the electric fluid in a very ſimple and convincing manner.

EXPERIMENT IX.

To ſhow the electric Attraction, and Repulſion by the electric Light.

Fix a pointed wire upon the prime Conductor with the point outward, and another like wire upou the inſulated rubber; then let the winch of the machine be turned, and the points of both wires will appear illuminated, *viz.* the former with a bruſh, and the latter with a ſtar. In this ſituation, take an excited glaſs tube, and bring it ſideway of the point of the wire fixed upon the prime Conductor, and you will ſee that the bruſh of rays iſſuing from the point, is turned ſideway, *i. e.* is repelled by the atmoſphere of the tube; and if the excited tube be held juſt oppoſite to the point, the bruſh will entirely vaniſh, becauſe both the tube and the point are electrified poſitively. If the excited tube be brought near the point of the wire fixed upon the rubber, the ſtar upon it will turn itſelf towards the tube; for this wire, being electrified negatively, will attract the electric fluid of the excited tube.

If this experiment be repeated with an excited ſtick of ſealing-wax, or any other electric negatively electrified, inſtead of the glaſs tube, it will be found that the bruſh proceeding from the wire fixed upon the prime Conductor, will turn itſelf towards the excited wax, &c. and the ſtar upon the point of the wire negatively electrified, will be diverted from it, or entirely ſuppreſſed, if the excited ſtick of ſealing-wax be brought juſt oppoſite to the point.

EXPERIMENT X.

The electrified Capillary Syphon.

Let a ſmall bucket of metal, full of water, be ſuſpended from the prime Conductor, and put in it a glaſs ſyphon of ſo narrow extremity, as the water will juſt drop from it. If in this diſpoſition of the apparatus the winch of the machine be turned, the water, which, when not electrified, only dropt from the extremity of the ſyphon, will now run in a full ſtream, which will even be ſubdivided into other ſmaller ſtreams; and if the experiment be made in the dark, it will appear beautifully illuminated.

EXPERIMENT XI.

The electrified Bells.

Fig. 10 of Plate II. repreſents an inſtrument having three bells, which are cauſed to ring by the power of electric attraction and repulſion. B is a braſs piece furniſhed with a hook, by which it may be ſuſpended from the rod proceeding from the extremity of the prime Conductor A. The two bells C, and E are ſuſpended by braſs chains; but the middle bell D, and the two ſmall braſs clappers between C D, and D E, are ſuſpended by ſilk threads. From the concave part of the bell D a braſs chain proceeds, which falls upon the table, and has a ſilk thread F at its extremity. The apparatus being diſpoſed as in the figure, if the cylinder of the machine be turned, the clappers will fly from bell to bell with a very quick motion, and the bells will ring as long as they are kept electrified.

The two bells C and E, being ſuſpended by braſs chains, are firſt electrified, hence they attract the clappers, communicate to them a little Electricity, and repel them to the unelectrified bell D, upon which the clappers depoſit their Electricity, and then run again to the bells C E, from which they acquire more Electricity, &c. If by holding the ſilk thread F, the chain of the middle bell be raiſed from the table, the bells, after ringing a little while, will ſtop, becauſe the bell D remaining inſulated, will ſoon become as ſtrongly electrified as either of the other two bells, in which caſe the clappers, having no opportunity to depoſit the Electricity that they acquire from the bells C, E, muſt conſequently ſtop.

If this experiment be made in the dark, ſparks will be ſeen between the clappers and the bells.

EXPERIMENT XII.

The Spider ſeemingly animated by Electricity.

Fig. 9 of Plate II. repreſents an electric jar, having a wire C D E faſtened on its outſide, which is bended ſo as to have its knob E, as high as the knob A. B is a ſpider made of cork, with a few ſhort threads run through it, to repreſent its legs. This ſpider is faſtened at the end of a ſilk thread, proceeding from the ceiling of the room, or from any other ſupport, ſo that the ſpider may hang mid-way between the two knobs A, E, when the jar is not charged. Let the place of the jar upon the table be marked; then charge the jar by bringing its knob A in contact with the prime Conductor, and replace it in its marked place. The ſpider will now begin to move from knob to knob, and continue this motion for a conſiderable time, ſometimes for ſeveral hours.

The inſide of the jar being charged poſitively, the ſpider is attracted by the knob A, which communicates to it a ſmall quantity of Electricity; the ſpider then becoming poſſeſſed of the ſame Electricity with the knob A, is repelled by it, and runs to the knob E, where it diſcharges its Electricity, and is then again attracted by the knob A, and ſo on. In this manner the jar is gradually diſcharged; and when the diſcharge is nearly compleated, the ſpider finiſhes its motion.

EXPERIMENT XIII.

The Spiral Tube.

Fig. 13 of Plate II. repreſents an inſtrument compoſed of two glaſs tubes C D, one within another, and cloſed with two knobbed braſs caps A, and B. The innermoſt of theſe tubes has a ſpiral row of ſmall round pieces of tin-foil, ſtuck upon its outſide ſurface, and laying at about one thirtieth of an inch from each other. If this inſtrument be held by one of its extremities, and its other extremity be preſented to the prime Conductor, every ſpark that it receives from the prime Conductor, will cauſe ſmall ſparks to appear between all the round pieces of tin-foil ſtuck upon the innermoſt tube, which in the dark affords a pleaſing ſpectacle; the inſtrument appearing encompaſſed by a ſpiral line of fire.

The ſmall round pieces of tin-foil are ſometimes ſtuck upon a flat piece of glaſs, A B C D, fig. 12, ſo as to repreſent curve lines, flowers, letters, &c. and they are illuminated after the ſame manner as the ſpiral tube; *i. e.* by holding the extremity C, or B in the hand, and preſenting the other extremity to the prime Conductor, when the machine is in motion.

Expe-

EXPERIMENT XIV.

The dancing Balls.

Fix a pointed wire upon the prime Conductor, with the point outward; then take a glaſs tumbler, graſp it with your hands, and preſent its inſide ſurface to the point of the wire upon the prime Conductor, while the machine is in motion; the glaſs in this manner will ſoon become charged; for its inſide ſurface acquires the Electricity from the point, and its outſide loſes its natural quantity of electric fluid through the hands, which ſerve as a coating. — This done, put a few pith-balls upon the table, and cover them with this charged glaſs tumbler. The balls will immediately begin to leap up along the ſides of the glaſs, as repreſented fig. 15, Plate II. and will continue their motion for a conſiderable time.

In this experiment the pith-balls are attracted and repelled by the electric fluid ſuperinduced upon the inſide ſurface of the glaſs, which they gradually conduct to the table or other conducting body upon which the glaſs is ſet; at the ſame time that the outward ſurface of the glaſs acquires the electric fluid from the contiguous air.

CHAP. XIII.

Further Properties of the Leyden Phial, or charged Electrics.

THE properties of charged electrics, plain as they may appear at firſt ſight, and conformable to the commonly-eſtabliſhed theory of Electricity, are yet, when attentively conſidered, far from being intirely underſtood, ſo as to require no further experiments, or leave no doubt in the mind of the ſpeculative Electrician. The firſt queſtion, that naturally occurs, in conſidering a charged phial, is, Where does the ſuperinduced electric fluid reſide? —— Is it lodged in the ſubſtance of the glaſs, or in the air contiguous to the ſurface of the phial? In the firſt caſe, if the electric fluid penetrates a certain quantity of the ſubſtance of the glaſs, it follows, that a glaſs plate may be given ſo thin, that the electric fluid may freely pervade its ſubſtance *. If ſuch a plate can be made, it will be eaſy, from thence, to determine how far the electric fluid can penetrate the ſubſtance of the glaſs, when charged in the uſual manner. In the ſecond caſe, if the electric fluid reſides in the air contiguous to the glaſs, it muſt repel that air, *i. e.* a glaſs bottle ſhould contain leſs air when charged, than when in its natural ſtate; but this is contrary to experience.

The late Mr. CANTON charged ſome thin glaſs balls of about an inch and a half in diameter, having tubes of about nine inches in length, and afterwards ſealed them hermetically. If theſe balls, when they were cold, were preſented to an electrometer, they ſhewed no ſign of Electricity; but if they were kept a little while near the fire, they then appeared ſtrongly electrical, and poſſeſſed of that kind of Electricity with which their inſide had been charged. Mr. CANTON diſcovered farther, that if theſe balls are kept under water, they retain their virtue for a conſiderable time, even for ſeveral years; but if they are often uſed, their power is ſoon exhauſted. It is obvious to remark, that the Electricity, which appears upon the outſide of theſe balls, when they are rendered hot, *i. e.* when the glaſs is rendered a Conductor by the heat, is not that Electricity, which properly conſtitutes the charge, but the ſuperfluous Electricity of their inſide *.

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* I have often blown glaſs balls ſo thin, that their thickneſs was leſs than one ſix-hundredth part of an inch, and have always obſerved, that they were capable of receiving a charge, which they retained for a conſiderable time, if they were not made very hot.

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* If a charged jar be inſulated, and diſcharged with an inſulated diſcharging rod, after the diſcharge both the ſides of the jar, together with the diſcharging rod, will be found poſſeſſed of the Electricity contrary to the Electricity of that ſide of the jar, which was touched laſt before the diſcharge; which ſhows that one ſide of a charged electric may contain a greater quantity of Electricity than that, which is ſufficient to balance the contrary Electricity of the oppoſite ſide. This redundant Electricity ſhould be carefully conſidered in performing experiments of a delicate nature.

As for the Electricity, which conſtitutes the charge, it being juſt ſufficient to balance the contrary Electricity of the oppoſite ſurface of the glaſs, it will loſe its power as ſoon as it is arrived to that ſurface, which in the caſe of the above-mentioned balls, it actually reaches, before it can act upon the electrometer.

The moſt remarkable phenomena produced by charged electrics, are exhibited with flat plates of glaſs, jointly charged, like a ſingle coated plate. If two glaſs plates, having plain ſurfaces, be placed one upon the other, and their outward ſurfaces be coated with tin-foil, in the uſual manner of coating a ſingle plate for the Leyden experiment, and then be charged, by preſenting one coating to the prime Conductor, and communicating the other with the earth, the plates (which we ſhall call A, and B) after having been charged, will adhere very firmly to one another, and if ſeparated, A, *viz.* that, whoſe coating was preſented to the prime Conductor, will appear poſitive on both ſides, and B negative on both ſides. If theſe plates are laid in contact as before they were charged, and are diſcharged by making a communication between the two coated ſides, they will be found ſtill to adhere to one another after the diſcharge; and if ſeparated, they will appear ſtill electrified, but with this remarkable difference, *viz.* that now A is negative on both ſides, and B poſitive on both ſides. If theſe plates, after being diſcharged, be ſeparated in the dark, flaſhes of light are perceivable between their internal ſurfaces. By laying the plates together, touching their coatings, and ſeparating them ſucceſſively, the flaſhes may be obſerved for a conſiderable number of times, diminiſhing by degrees, until they quite vaniſh.

Father BECCARIA explains theſe, and other ſimilar phenomena of charged as well as of excited electrics, by the following principle, which he diſtinguiſhes by the name of *vindicating Electricity.* When two bodies, either a Conductor and an electrified electric, or two contrarily and equally electrified electrics, are joined together, they adhere to each other, and their

Electricities diſappear; but as ſoon as they are ſeparated, the electrics recover their Electricities *. How far this principle can be of uſe to explain the phenomena of charged glaſs, &c. I will not take upon me to determine. It would exceed too far the limits of my work, if I were to enumerate and account for all the particulars. When the principle is expreſſed, the ingenious reader may eaſily apply it to explain the effects. I ſhall only mention an obſervation of Mr. HENLY, relative to this ſubject, which ſeems not conformable to Father BECCARIA's theory; and with that I ſhall conclude this Part of my work. Says Mr. HENLY, in one of his papers preſented to the Royal Society, in which he deſcribes the above-mentioned experiments of the two glaſs plates: — "Crown-glaſs, "that is, the glaſs commonly uſed for "ſaſh-windows, though ſo much thinner, "ſucceeds in this experiment as well as "the plate-glaſs; but what is very re-"markable, the Dutch plates, when treat-"ed in the ſame manner, have each a po-

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* See BECCARIA's Artificial Electricity, Part II. Sec. VI.

"ſitive and negative ſurface, and the Elec-
"tricity of both ſurfaces of both plates
"is exchanged for the contrary Electri-
"city in the diſcharge. If a clean, dry,
"uncoated plate of looking-glaſs be
"placed between the coated looking-glaſs
"plates, or between the plates of crown-
"glaſs, it appears, after charging, to be
"negatively electrified on both ſides; but
"if it be placed between the Dutch
"plates, it acquires, like them, a poſitive
"Electricity on one ſurface, and a nega-
"tive Electricity on the other."

In another paper Mr. HENLY further obſerves, that if the Dutch plates are ſeparated immediately after being charged, they will then act like two plates of looking-glaſs, *i. e.* one of them will be poſitive, and the other negative on both ſides; but if a little time be allowed before the plates be ſeparated, the experiment will conſtantly ſucceed as above *.

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* To this ſecond edition, a diſſertation on the *vindicating Electricity* has been added in the Appendix; which will ſhew, by plain experiments, this wonderful property of glaſs, &c. whilſt this chapter has been here reprinted juſt as it was publiſhed in the firſt edition.

PART

PART IV.

NEW EXPERIMENTS IN ELECTRICITY.

THE laws of Electricity, together with the experiments neceſſary for their demonſtration, having already been deſcribed, in as compendious a manner as could be done without obſcurity, I ſhall, in the laſt Part of this Work, relate ſuch new experiments and obſervations as I have made during the courſe of about two years; in which time I have purſued the Science of Electricity, with a particular view to diſcover, if poſſible, the unknown cauſe of ſeveral electrical phenomena, eſpecially thoſe relative to atmoſpherical Electricity.

The firſt inſtrument that I made uſe of to obſerve the Electricity of the atmoſphere, was an electrical kite, which I had conſtructed, not with a view to obſerve the Electricity of the air; for this, I thought, was very weak, and ſeldom to be obſerved; but as an inſtrument which could be occaſionally uſed in time of a thunder-ſtorm, in order to obſerve the Electricity of the clouds. The kite, however, being juſt finiſhed, together with its ſtring, which contained a braſs wire through its whole length, I raiſed it the 31ſt of Auguſt 1775, at ſeven of the clock in the afternoon, the weather being a little cloudy, and the wind juſt ſufficient for the purpoſe. The extremity of the ſtring being inſulated, I applied my fingers to it; which, contrary to my expectation, drew very vivid and pungent ſparks: I charged a coated phial at the ſtring ſeveral times; but I did not then obſerve the quality of the Electricity. This ſucceſsful experiment induced me to raiſe the kite very often, and to keep it up for ſeveral hours together; thinking that if any periodical Electricity, or any change of its quality took place in the atmoſphere, it might very probably be diſcovered by this inſtrument. In the following two Chapters I ſhall deſcribe the conſtruction of the electrical kite, with its appurtenances; and ſhall tranſcribe the moſt remarkable part of my journal relative to the kite; *i. e.* deſcribing ſuch experiments only which are moſt remarkable, and do not happen very commonly; for although I have uſed my kite ſometimes ten, and more times in a week, and at any hour of the day or night, yet as the greateſt part of thoſe experiments are only of uſe to confirm a few laws of atmoſpherical Electricity, I ſhall leave their particular detail, and ſhall only ſubjoin thoſe laws at the end of the ſecond chapter.

CHAP. I.

The Conſtruction of the electrical Kite, and other Inſtruments uſed with it.

THE firſt electrical kite that I conſtructed, was ſeven feet high; and it was made of paper, with a ſtick or ſtraiter, and a cane-bow, like the kites commonly uſed by ſchool-boys. On the upper part of the ſtraiter I fixed an iron ſpike, projecting about a foot above the kite, which I then thought was abſolutely neceſſary to collect the Electricity; and I covered the paper of the kite with turpentine, in order to defend it from the rain. This kite, perfect as I thought it to be in its conſtruction, and fit for the experiments for which it was intended, ſoon manifeſted its imperfections, and, after being raiſed a few times, it became quite unfit for farther uſe; it being ſo large, and conſequently heavy, that it could not be uſed, except when the wind was ſtrong; and then, after much trouble in raiſing and drawing it in, it often received ſome damage: which ſoon obliged me to conſtruct other kites upon a different plan, in order to aſcertain which method would anſwer the beſt for my purpoſe. I gradually leſſened their ſize, and varied their form, till I obſerved upon trial, that a common ſchool-boy's kite was as good an electrical kite as mine. In conſequence of which, I conſtructed my kites in the moſt ſimple manner, and in nothing different from the children's kites, except that I covered them with varniſh, or with well-boiled linſeed-oil, in order to defend them from the rain; and I covered the back part of the ſtraiter with tin-foil, which, however, has not the leaſt power to increaſe its Electricity. I alſo furniſh the upper extremity of the ſtraiter with a ſlender wire pointed, which, in time of a thunder-ſtorm, may perhaps draw the Electricity from the clouds ſomewhat more effectually; but in general, I find, as it will appear in the account of the experiments, that it does not in the leaſt affect the Electricity at the ſtring. The kites that I generally have uſed are about four feet high, and little above two feet wide. This ſize, I find, is the moſt convenient, becauſe it renders them eaſy to be managed, and, at the ſame time, they can draw a ſufficient quantity of ſtring. As for ſilk or linen kites, they require a good deal of wind to be raiſed; and then they are not ſo cheap, nor ſo eaſy to be made, as paper kites are. The ſtring ſometimes breaks, and the kite is loſt, or broken; for which reaſon theſe kites ſhould be made as cheap and as ſimple as poſſible.

The ſtring is the moſt material part of this apparatus; for the Electricity produced is more or leſs, according as the ſtring is a better or a worſe Conductor. The ſtring which I made for my large kite, conſiſted of two threads of common twine, twiſted together with a braſs wire between the ſtrands. This ſtring ſerved very well for two or three trials, but, on examination, I ſoon found, that the wire in it was broken in many places, and it was continually ſnapping; the metallic continuation, therefore, being ſo often interrupted, the ſtring became ſoon ſo bad, that it acted nothing better than common twine without a wire. I attempted to mend it, by joining the broken pieces of wire, and working into the twine another wire, which proved a very laborious work; but the remedy had very little effect; the wire breaking again after the firſt trial: which determined me to adopt other methods; and, after ſeveral experiments,

ments, I found that the beſt ſtring was one, which I made by twiſting a copper thread * with two very thin threads of twine. Strings like this I have uſed for the greateſt part of my experiments with the kite, and I find them to be exceedingly uſeful, and fit for the purpoſe. Silver or gold thread would do much better to twiſt with the twine, becauſe they are much thinner than copper thread, and, in conſequence, the ſtring would be much lighter; but, at the ſame time, it is to be conſidered, that gold or ſilver thread is much dearer than copper thread.

I have attempted to render the twine a good Conductor of Electricity, by covering it with conducting ſubſtances; as lamp-black, powder of charcoal, very fine emery, and other ſubſtances, mixing them with diluted gum-water; but this method improves the ſtring very little, and for a

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* I mean ſuch a thread of copper as is uſed for trimmings, &c. in imitation of gold threads; which are nothing more than ſilk, or linen threads, covered with a thin lamina of copper.

very ſhort time; for the ſaid conducting ſubſtances are ſoon rubbed off the twine. Mr. NAIRNE informed me, that he had uſed to ſoak the ſtring of his electrical kite in a ſtrong ſolution of ſalt, which rendered it a good Conductor, ſo far as it attracted the moiſture of the air. In conſequence of this information, I ſoaked in ſalt-water a long piece of twine, and, by raiſing a kite with it, I found that it conducted the Electricity pretty well; but I thought it much inferior to the above-deſcribed ſtring with the copper thread: beſides, the ſalted ſtring in wet weather not only leaves part of the ſalt upon the hands of the operator, and, in conſequence, renders them unfit to manage the reſt of the apparatus, but it marks a white ſpot wherever it touches the clothes.

In raiſing the kite when the weather is very cloudy and rainy, in which time there is fear of meeting with great quantity of Electricity, I generally uſe to hang upon the ſtring A B, fig. 8. Plate II. the hook of a chain C, the other extremity of which falls upon the ground. Sometimes

I uſe

I uſe another caution beſides, which is, to ſtand upon an inſulating ſtool; in which ſituation I think, that if any great quantity of Electricity, ſuddenly diſcharged by the clouds, ſtrikes the kite, it cannot affect much my perſon. As to inſulated reels, and ſuch-like inſtruments, that ſome gentlemen have uſed to raiſe the kite, without danger of receiving any ſhock; fit for the purpoſe as they may appear to be in theory, they are yet very inconvenient to be managed. Except the kite be raiſed in time of a thunder-ſtorm, there is no great danger for the operator to receive any ſhock. Although I have raiſed my electrical kite hundreds of times without any caution whatever, I have very ſeldom received a few exceedingly ſlight ſhocks in my arms. In time of a thunder-ſtorm, if the kite has not been raiſed before, I would not adviſe a perſon to raiſe it while the ſtormy clouds are juſt overhead; the danger in ſuch time being very great, even with the precautions above-mentioned: at that time, without raiſing the kite, the Electricity of the clouds may be obſerved by a cork-ball electrometer held in the hand in an open place, or if it rains, by my electrometer for the rain; which will be deſcribed hereafter.

When the kite has been raiſed, I generally introduce the ſtring through a window in a room of the houſe, and faſten it to a ſtrong ſilk lace, the extremity of which is generally tied to a heavy chair in the room. In fig. 8. of Plate III. A B repreſents part of the ſtring of the kite which comes within the room; C repreſents the ſilk lace; D E, a ſmall prime Conductor, which, by means of a ſmall wire, is connected with the ſtring of the kite; and F repreſents the quadrant electrometer, fixed upon a ſtand of glaſs covered with ſealing-wax, which I uſed to put near the prime Conductor, rather than to fix it in a hole upon the Conductor, becauſe the ſtring A B ſometimes ſhakes ſo as to pull the prime Conductor down; in which caſe the quadrant electrometer remains ſafe upon the table, otherwiſe it would be broken, as I have often experienced before I thought of this method. G repreſents a glaſs tube, about eighteen inches long, with a knobbed wire cemented to its extremity; which inſtrument I uſe to obſerve the quality of the Electricity, when the Electricity of the kite is ſo ſtrong that I think it not ſafe to come very near the ſtring. The method is as follows: — I hold the inſtrument by that extremity of the glaſs tube which is the fartheſt from the wire, and touch the ſtring of the kite with the knob of its wire, which, being inſulated, acquires a ſmall quantity of Electricity from it; which is ſufficient to aſcertain its quality when the knob of the inſtrument is brought near an electrified electrometer. Sometimes, when I raiſe the kite in the night-time, out of the houſe, and where I have not the convenience of obſerving the quality of its Electricity by the attraction and repulſion, or even by the appearance of the electric light, I make uſe of a coated phial, which I can charge at the ſtring, and, when charged, put into my pocket; wherein it will keep charged even for ſeveral hours *. By making uſe of this inſtrument,

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* The conſtruction of this phial is as follows: — Beſides the coating on the inſide and outſide, that this phial has, like any other of the ſame kind, a glaſs tube,

ſtrument, I am obliged to keep the kite up no longer than is neceſſary to charge the phial, in order to obſerve the quality of the Electricity in the atmoſphere; for after the kite has been drawn in and brought home, I can then examine the Electricity of the inſide of the phial, which is the ſame as that of the kite.

tube, open at both ends, is cemented into its neck, and proceeds within the phial, having a ſmall wire faſtened to its lower extremity, which touches the inſide non-electric coating. The wire with the knob of this phial is cemented into another glaſs tube, which is nearly twice as long, and ſmaller than the tube cemented into the neck of the phial. The wire is cemented ſo, that only its knob projects out of one end, and a ſmall length of it out of the other end of the tube. If this piece with the wire be held by the middle of the glaſs tube, it may be put in or out of the tube which is in the neck of the phial, ſo as to touch the ſmall wire at the lower extremity of it, and that without diſcharging the phial, if it is charged. I have kept ſuch a phial charged for ſix weeks together; and probably it would keep much longer, if it were to be tried. The ingenious young Electrician may make uſe of ſuch a phial for ſeveral diverting purpoſes. — The piece of glaſs which ſerves to hold the wire by, is rather better to be fixed above than below the ball. In this caſe, the ball is perforated quite through, and the wire projects a ſhort way above it; to which the glaſs tube is cemented.

When the Electricity of the kite is very ſtrong, I fix a chain, communicating with the ground, at about ſix inches diſtance from the ſtring; which may carry off its Electricity, in caſe that this ſhould increaſe ſo much as to put the by-ſtanders in danger.

Beſides the above-deſcribed apparatus, I have occaſionally uſed ſome other inſtruments, which I have often varied, according as ſome particular experiments required; but, as they are of no great conſequence, I ſhall omit to deſcribe them. It is only neceſſary, before I enter into the narration of the principal experiments performed with the kite, to give an idea of the ſtandard of my quadrant electrometer; which may, very probably, ſhew the ſame intenſity of Electricity under a number of degrees different from the other inſtrument of the ſame kind. When the kite is flying, and the apparatus is diſpoſed as in fig. 8. of Plate III. I bring, under the extremity E of the prime Conductor, a little bran, held upon a tin plate, and obſerve, that when the index of the electrometer is at ten degrees, the prime Conductor begins to attract the bran at the diſtance of about three-fifths of an inch; when the index is at twenty degrees, the prime Conductor attracts the bran at the diſtance of about one inch and a quarter; when the index is at thirty degrees, the bran begins to be attracted at the diſtance of two inches and one-fifth. Theſe diſtances vary, as the weather changes its degree of dryneſs; but in froſty weather I obſerve them conſtantly as above.

CHAP. II.

Experiments performed with the electrical Kite.

SEptember the 2d, 1775. The weather being very cloudy, and actually raining, the kite was raiſed at eight o'clock P. M. with two hundred yards of ſtring, which had a braſs wire through its whole length. The wind was from the ſouth and very ſtrong. The Electricity at the ſtring was negative, and juſt ſufficient to charge a half-pint phial ſo as to give a ſhock ſenſible to the elbows. The kite, after being up for about one hour, fell to the ground, having its paper, which was not properly varniſhed, almoſt intirely torn off by the violence of the wind and the rain.

September the 14th. The kite was raiſed with a ſtrong north wind at half paſt three P. M. The Electricity was poſitive, and pretty ſtrong, the index of the electrometer being generally about 20°*. The weather was rather cold, and very thick clouds were gradually approaching the zenith. The kite was pulled down at half paſt four P. M.

N. B. At night the aurora borealis was very ſtrong, and ſeveral flaſhes of lightning were ſeen near the horizon towards the north.

September the 23d. A ſmall kite was raiſed at half paſt ten o'clock in the morning,

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* The index of the electrometer in general raiſes higher or falls lower, according as the kite comes nearer to, or goes farther from the zenith; the length of the ſtring remaining the ſame.

ing, and it was kept up for eleven hours ſucceſſively, *viz.* till half paſt nine P. M. The ſtring, which was only a common twine, without a wire, was conſtantly electrified poſitively, although in a very ſmall degree. About nine o'clock the Electricity appeared ſtronger, ſo that a ſmall phial, charged at the ſtring, gave a pretty ſenſible ſhock. The weather was very clear, and warm; but in the night no aurora borealis, or any other electrical appearance, was perceived. The wind was eaſt by ſouth, and ſo weak that the kite was kept up with great difficulty.

October the 10th, 1775. The weather being clear, and the wind blowing ſtrong from the ſouth weſt, the kite was raiſed at eleven o'clock A. M. with ninety yards of ſtring, which had a copper thread twiſted in*. The wind, during the experiment, increaſed and decreaſed ſeveral times; and the Electricity, which was poſitive, as it appeared by the index of the electrometer, alſo increaſed and decreaſed. At noon the violence of the wind cauſed the kite to fall. At half paſt four o'clock, the wind being a a little more moderate, the kite was raiſed again. The Electricity was alſo poſitive, and ſeemed rather ſtronger than it had been in the morning. The weather at this time was cloudy; the clouds appearing much thicker near the horizon than about the zenith. The kite was pulled down at half paſt five o'clock, and at half after ſeven was raiſed again; every phenomenon continuing the ſame. At eight o'clock, while I was pulling the kite in, I inſulated the ſtring when only thirty-five yards of it were out, and was ſurpriſed to find, that now the Electricity was as ſtrong as it had been, when all the ſtring was out, which was ninety yards long. It muſt however be remarked, that at this time a few flaſhes of lightning were ſeen among the clouds, which were pretty thick about the horizon. At a quarter paſt eleven o'clock the kite was raiſed again, which was the fourth time of raiſing it that day; the weather then being very clear, and the wind the ſame as in the afternoon. The Electricity was very weak, but conſtantly poſitive. The kite was pulled down, after having been up a few minutes only.

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* Such ſtring as this was uſed in all the following experiments.

October the 16th. At about two P. M. a thick fog being juſt cleared up, the weather became clear, and the wind began to blow from the ſouth ſouth weſt. The kite was raiſed with one hundred and twenty yards of ſtring, and it was kept up no longer than a quarter of an hour. The Electricity was poſitive, and pretty ſtrong; the index of the electrometer being about 15°. At half paſt three o'clock the kite was raiſed again, the weather being very little cloudy. At half paſt four o'clock the clouds became very thick, and in a ſhort time it began to rain, which increaſed the Electricity of the kite, without changing its quality; the index of the electrometer arriving to 20°. The kite was pulled down at five o'clock.

October the 18th. After having rained a great deal in the morning, and night before, the weather became a little clear in the afternoon, the clouds appearing ſeparated,

rated, and pretty well defined. The wind was weſt, and rather ſtrong, and the atmoſphere in a temperate degree of heat. In theſe circumſtances, at three P. M. I raiſed my electrical kite with three hundred and ſixty feet of ſtring. After that the end of the ſtring had been inſulated, and a leather-ball, covered with tin-foil, had been hung to it, I tried the power and quality of the Electricity, which appeared to be poſitive, and pretty ſtrong. In a ſhort time a ſmall cloud paſſing over, the Electricity increaſed a little; but the cloud being gone, it decreaſed again to its former degree. The ſtring of the kite was now faſtened by the ſilk lace to a poſt in the yard of the houſe wherein I lived, which was ſituated near Iſlington, and I was repeatedly charging two coated phials, and giving ſhocks with them:—while I was ſo doing, the Electricity, which was ſtill poſitive, began to decreaſe, and in two or three minutes time it became ſo weak, that it could be hardly perceived with a very ſenſible cork-ball electrometer. Obſerving at the ſame time that a large and black cloud was approaching the zenith (which, no doubt, cauſed the decreaſe of the Electricity) indicating imminent rain, I introduced the end of the ſtring through a window, in a firſt-floor room, wherein I faſtened it by the ſilk lace to an old chair. The quadrant electrometer was ſet upon the ſame window, and was, by means of a wire, connected with the ſtring of the kite. Being now three quarters of an hour after three o'clock, the Electricity was abſolutely unperceivable; however, in about three minutes time, it became again perceivable, but now upon trial was found to be negative; it is therefore plain, that its ſtopping was nothing more than a change from poſitive to negative, which was evidently occaſioned by the approach of the cloud, part of which by this time had reached the zenith of the kite, and the rain alſo had begun to fall in large drops.—The cloud came farther on;—the rain increaſed, and the Electricity keeping pace with it, the electrometer ſoon arrived to 15°. Seeing now, that the Electricity was pretty ſtrong, I began again to charge the two coated phials, and to give ſhocks with them; but the phials had not been charged above three or four times, before I perceived that the index of the electrometer was arrived to 35°, and was keeping ſtill increaſing. The ſhocks now being very ſmart, I deſiſted from charging the phials any longer; and, conſidering the rapid advance of the Electricity, thought to take off the inſulation of the ſtring, in caſe that if it ſhould increaſe farther, it might be ſilently conducted to the earth, without cauſing any bad accident, by being accumulated in the inſulated ſtring. To effect this, as I had no proper apparatus near me, I thought to remove the ſilk lace, and faſten the ſtring itſelf to the chair; accordingly, I diſengaged the wire that connected the electrometer with the ſtring; laid hold of the ſtring; untied it from the ſilk lace, and faſtened it to the chair; but while I effected this, which took up leſs than half a minute of time, I received about a dozen, or fifteen very ſtrong ſhocks, which I felt all along my arms, in my breaſt, and legs; ſhaking me in ſuch a manner, that I had hardly power enough to effect my purpoſe, and to warn the people in the room to keep their diſtance. As ſoon as I took my hands off the ſtring, the Electricity (in conſequence of the chair being a bad Conductor) began to ſnap between the ſtring and the ſhutter of the window, which was the neareſt body to it. The ſnappings, which were audible at a good diſtance out of the room, ſeemed firſt iſochronus with the ſhocks which I had received, but in about a minute's time, oftner; ſo that the people of the houſe compared their ſound to the rattling noiſe of a jack going when the fly is off. The cloud now was juſt over the kite; it was black, and well defined, of almoſt a circular form, its diameter appearing to be about 40°; the rain was copious, but not remarkably heavy. As the cloud was going off, the electrical ſnapping began to weaken, and in a ſhort time became unaudible. I went then near the ſtring, and finding the Electricity weak, but ſtill negative, I inſulated it again, thinking to keep the kite up ſome time longer; but obſerving that another larger and denſer cloud was approaching apace towards the zenith, as I had then no proper apparatus at hand, to prevent every poſſible bad accident, I reſolved to pull the kite in; accordingly a gentleman, who was by me, began pulling it in, while I was winding up the ſtring. The cloud was now very nearly over the kite, and the gentleman, who was pulling in the ſtring, told me, that he had received one or two ſlight ſhocks in his arms, and that if he were to feel one more, he would certainly let the ſtring go; upon which I laid hold of the ſtring, and pulled the kite in as faſt as I could, without any farther obſervation; being then ten minutes after four o'clock.

N. B. There was neither thunder or lightning perceived that day, nor indeed for ſome days before or afterwards.

November the 8th, 1775. The wind being north-weſt, and juſt ſufficient, the kite was raiſed at three quarters paſt eleven A. M. with one hundred and twenty yards of ſtring. The Electricity was poſitive, and weak, the weather being cloudy. At noon the clouds grew thicker, and the Electricity quite vaniſhed; however, in a few ſeconds it returned, and from this time it evidently kept increaſing and decreaſing, according as the clouds became thinner or thicker. At forty minutes after one o'clock the Electricity vaniſhed again; a thick cloud then covering almoſt the whole hemiſphere; but as a little rain began to fall, the Electricity returned, and it was ſtill poſitive. At three quarters paſt three o'clock the clouds began to grow thin, and the Electricity increaſed a little; but at this time I was obliged to pull the kite in. The index of the electrometer in this experiment ſeldom arrived to 6°.

November the 16th. The weather being very clear and froſty, the kite was raiſed at a quarter paſt ten A. M. with one hundred and twenty yards of ſtring. The Electricity was poſitive, and pretty ſtrong, the index of the electrometer going from 9° to 15°; raiſing as the wind blew ſtronger, and the kite was more elevated, and *vice verſa*. At a quarter paſt three o'clock the wind, which was north-north-weſt, intirely failing, the kite fell.

November the 17th. The weather being exceedingly damp, and the fog ſo denſe, that the houſes at about a quarter of a mile diſtance could not be diſtinguiſhed, the kite was raiſed at two P. M. with one hundred and ten yards of ſtring, while it was raining, but very little. The Electricity was poſitive, and ſo weak that the cork-balls of an electrometer diverged about three quarters of an inch. The wind being very violent, I was obliged to pull the kite in, after having been up for about five minutes.

December the 5th, 1775. The weather being equally cloudy, and the wind weſt by north, and hardly ſufficient, the kite was raiſed at a quarter paſt three P. M. with one hundred and twenty yards of ſtring. The Electricity was poſitive, and ſo weak as to cauſe the cork-balls of an electrometer to diverge about an inch. At a little after four o'clock the kite was pulled in; and at eight o'clock in the evening it was raiſed again. At this time the Electricity was much ſtronger than in the afternoon, but conſtantly poſitive. The weather clearing up, the clouds were driven away by the wind, which was now a little ſtronger than in the afternoon. At forty minutes after eight o'clock the ſky was clear, the moon and ſtars appearing very bright; except that a few thin clouds were yet to be ſeen near the horizon. The index of the electrometer was now going from 15° to 20°. At ten minutes after nine o'clock the kite was drawn in.

N. B. No aurora borealis was to be ſeen.

December the 20th. The weather being cloudy and hazy, the kite was raiſed at three quarters after ten o'clock A. M. with one hundred and forty yards of ſtring. The Electricity was poſitive, and pretty ſtrong, the index of the electrometer going from 16° to 21°. At half paſt one P. M. the weather growing a little clearer, I pulled the kite down; and, after having interpoſed a ſilk ribband between its loop and the extremity of the ſtring, ſo as to inſulate the kite, I raiſed it again with the ſame length of ſtring; and, after I had inſulated the lower extremity of the ſtring, I obſerved that the intenſity of the Electricity, as it appeared by the index of the electrometer,

trometer, was, as nearly as could be determined, the ſame as before, *i. e.* when the kite was not inſulated with reſpect to the ſtring.

At two o'clock P. M. I pulled the kite down, and found upon obſervation, that the ſilk ribband had contracted no moiſture, ſo that the kite was perfectly inſulated by it. This experiment of inſulating the kite I have often repeated at other times, and have always met with the ſame ſucceſs; hence it appears, that it is the ſtring, and not the kite, which in general collects the Electricity from the air. The kite therefore in general is only uſeful to extend the ſtring high into the open air.

January the 4th, 1776. The froſt having been very hard during the day and night before, the wind began to blow very ſtrong from the ſouth at two o'clock A. M. which occaſioned a ſudden thaw and a copious rain. At eight o'clock A. M. at which time the kite was raiſed, the hemiſphere appeared like a uniform dark canopy, under which ſeveral ſmall, irregular, and darker clouds were running very faſt; the rain was conſtant, but not remarkably heavy. As ſoon as the ſtring of the kite was inſulated, the Electricity, which was negative, began to ſnap from it, to the ſhutter of the window and other bodies near; the index of the electrometer arrived to 40°, and it would have certainly gone farther, if the apparatus had been drier; but the air was ſo damp, that it was almoſt impoſſible to keep any part of the apparatus ſufficiently free from moiſture. The Electricity, however, gradually decreaſed, ſo that at ten o'clock A. M. at which time the kite was pulled in, the index of the electrometer was at a little above 12°. The coated phials in this experiment were charged ſurpriſingly quick; three or four ſeconds of time being ſufficient to charge two half-pint phials completely.

January the 11th. The ground was covered with ice and ſnow, and the atmoſphere was ſo hazy, that the houſes at a mile diſtance could not be perceived. The wind was ſouth-eaſt by ſouth, and juſt ſufficient to raiſe the kite, which was raiſed at three o'clock P. M. with one hundred and twenty-four yards of ſtring, and kept up till half an hour after midnight. When the kite was firſt raiſed it began to thaw, but as ſoon as it was dark it began to freeze again very hard. The Electricity was poſitive, and pretty ſtrong, the index of the electrometer being about 13°. At half paſt four o'clock I let out thirty-four yards more of ſtring, ſo that all the ſtring the kite now had, was one hundred and fifty-eight yards. With this addition of ſtring the Electricity increaſed, ſo that the index of the electrometer arrived to 17°. At half after five o'clock the wind began to increaſe, and the Electricity to decreaſe, until the index of the electrometer arrived to 6°. At three quarters paſt ſix o'clock the index of the electrometer was about 13°, and at ſeven o'clock it arrived to 20°; the wind being now quite eaſt. At a quarter paſt ſeven o'clock the index of the electrometer was about 25°. From this time the wind and the Electricity began both to decreaſe, ſo that at nine o'clock the index of the electrometer was about 10°. At eleven o'clock the wind increaſed. At twelve o'clock the wind was very ſtrong, and the index of the electrometer was about 6°. At half paſt twelve o'clock the index of the electrometer was between 3° and 4°; but the wind being grown very violent, the ſtring broke very near the window, and was loſt with the kite.

N. B. A few minutes after the kite was loſt, it began to ſnow copiouſly.

January the 26th. The froſt being very intenſe, as it had been for about three weeks, and actually ſnowing, I raiſed the kite, with ſeventy yards of ſtring; but before the ſtring was inſulated, it ceaſed to ſnow, and the weather began to clear up, and ſoon became very ſerene. The Electricity was poſitive, and very ſtrong, the index of the electrometer being about 32°. At eleven o'clock the ſtring broke, and the kite fell, after having been up for above three quarters of an hour.

February the 17th, 1776. The weather being cloudy, rainy, and ſo hazy, that the houſes at half a mile diſtance could not be diſcerned, the kite was raiſed at three quarters paſt eleven o'clock A. M. with one hundred and ſeventy-five yards of ſtring. The wind was pretty ſtrong; the Electricity was negative, and alſo ſtrong; the index of the electrometer being about 20°. In about five minutes time the rain ceaſed, the wind weakened, and ſhifted a little towards the ſouth; and the Electricity changed from negative to poſitive. The index of the electrometer was now about 15°. In two or three minutes time, it began to rain again, and continued ſo for the greateſt part of that day; the wind became very weak, and the Electricity changed again from poſitive to negative, and continued ſo till half an hour after noon; at which time the wind became ſo weak that I was obliged to pull the kite in.

February the 19th. The ſky being full of pretty well defined clouds, and the wind weſt-north-weſt, the kite was raiſed at half paſt three o'clock P. M. with one hundred and ſeventy-five yards of ſtring. The Electricity was poſitive and ſtrong, the index of the electrometer going from 10° to 20°. At three quarters paſt three o'clock a denſe cloud paſſed over the kite, which occaſioned the index of the electrometer to deſcend to 4°. As the cloud went away, the electrometer elevated its index. At four o'clock the kite was pulled down.

April the 8th, 1776. The weather was clear, and the northern light very ſtrong. The kite was raiſed for a few minutes at nine o'clock P. M. with one hundred and ſeventy-five yards of ſtring, the wind being north-north-weſt, and pretty ſtrong. The Electricity was poſitive, and, as I could judge, the index of the electrometer would have arrived to 15°.

May the 15th, 1776. The weather being cloudy, and the wind north, the kite was raiſed at three o'clock P. M. with one hundred and ſeventy yards of ſtring. The Electricity was at firſt exceedingly weak, and, as I imagine (for I had not time to examine it) poſitive. But a denſe cloud paſſing over the kite, the Electricity vaniſhed;

niſhed; and, as a few drops of rain fell, a very weak negative Electricity appeared, which ſoon increaſed, ſo as to cauſe the index of the electrometer to arrive to 15°. The rain, however, in a few minutes ceaſed, and the Electricity gradually decreaſed and vaniſhed. A very weak poſitive Electricity immediately took place; but, as another denſer cloud paſſed over, and a few very ſmall drops of rain fell, the poſitive Electricity vaniſhed, and the negative took place. The cloud and rain ſoon went off, and the Electricity became again poſitive, and continued ſo till the kite was pulled down. According as the clouds, which paſſed continually over the kite, were thinner or thicker, ſo the Electricity was more or leſs intenſe; ſometimes cauſing the index of the electrometer to arrive to 5°, and at other times being ſcarce perceiveable with the cork-ball electrometer. At five o'clock the kite was pulled in, the weather being then pretty clear, and the index of the electrometer at 3°. The wind, during this experiment, was ſtronger or weaker, according as the clouds which paſſed over were thicker or thinner. At half paſt ſeven o'clock in the evening of the ſame day, the kite was raiſed again, with the ſame length of ſtring, the wind being then rather ſtrong, and the weather pretty clear. The Electricity was poſitive, and the index of the electrometer ſtood at 10°; but as ſome clouds came from the north, the Electricity began to decreaſe, and by eight o'clock it juſt ſeparated the balls of an electrometer, the hemiſphere being then entirely covered by clouds. At half paſt eight o'clock the kite was pulled down, the clouds over the kite being then very thin, and the index of the electrometer at 5°.

June the 4th, 1776. The weather being cloudy, and the wind on the ſouth-ſouth-weſt, the kite was raiſed at one o'clock P. M. with one hundred and ſeventy yards of ſtring. The Electricity was poſitive, and the index went from 1° to 7°. At three quarters paſt one o'clock the clouds began to be diſſipated, and the Electricity increaſed a little. At two o'clock the kite was pulled in, June the 17th. The weather being cloudy, and the wind ſouth-weſt, the kite was raiſed at five o'clock P. M. with one hundred and ſeventy yards of ſtring. The Electricity was poſitive, and the index of the electrometer went from 10° to 16°. In this experiment the clouds, whether thicker or thinner, ſeemed to have no effect upon the Electricity of the kite. At a quarter paſt ſix o'clock the kite was pulled in.

June the 20th. The weather being cloudy, and the wind eaſt, and juſt ſufficient, the kite was raiſed at three quarters paſt three P. M. with one hundred and ſeventy yards of ſtring. The Electricity was poſitive, and the index of the electrometer ſtood about 8°. At five o'clock the weather began to clear up, and the Electricity to increaſe; ſo that in half an hour's time, the index of the electrometer arrived to 17°; and at ſix o'clock it ſtood at 25°. But the wind ſuddenly failing about this time, the kite fell.

January the 8th, 1777. The weather

being froſty and clear, and the wind north, and pretty ſtrong, the kite was raiſed at four o'clock P. M. with one hundred and ſeventy yards of ſtring. The Electricity was poſitive and ſtrong, the index of the electrometer being at 36°. The ſpark taken from the ſmall prime Conductor was remarkably pungent in this experiment, although it was hardly a quarter of an inch long. At a quarter paſt five o'clock the kite was pulled in.

General Laws, deduced from the Experiments performed with the electrical Kites.

I. The air appears to be electrified at all times; its Electricity is conſtantly poſitive, and much ſtronger in froſty, than in warm weather *; but it is by no means leſs in the night than in the day-time †.

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* My obſervations upon the Electricity of the atmoſphere have been made in almoſt every degree of temperature, from 15° to 80° of Farenheit's thermometer.

† In all my experiments, it happened only once that the ſtring of the kite gave no ſigns of Electricity; it was one afternoon, when the weather was warm,

II. The preſence of the clouds generally leſſens the Electricity of the kite: ſometimes it has no effect upon it; and it is very ſeldom that it increaſes it a little.

III. When it rains, the Electricity of the kite is generally negative, and very ſeldom poſitive.

IV. The aurora borealis ſeems not to affect the Electricity of the kite.

V. The electrical ſpark taken from the ſtring of the kite, or from any inſulated Conductor connected with it, eſpecially when it does not rain, is very ſeldom longer than a quarter of an inch; but it is exceedingly pungent. When the index of the electrometer is not higher than 20°, the perſon that takes the ſpark will feel

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warm, and the wind ſo weak, that the kite was raiſed with difficulty, and could hardly be kept up for a few minutes; in the evening, however, the wind, which in the day-time had been north-weſt, ſhifted to the north-eaſt, blowing a little ſtronger; I then raiſed the kite again, being half paſt ten o'clock, and obtained, as uſual, a pretty ſtrong poſitive Electricity.

the effect of it in his legs; it appearing more like the diſcharge of an electric jar, than the ſpark taken from the prime Conductor of an electrical machine.

VI. The Electricity of the kite is in general ſtronger or weaker, according as the ſtring is longer or ſhorter; but it does not keep any exact proportion to it: the Electricity, for inſtance, brought down by a ſtring of a hundred yards, may raiſe the index of the electrometer to 20°; when, with double that length of ſtring, the index of the electrometer will not go higher than 25°.

VII. When the weather is damp, and the Electricity is pretty ſtrong, the index of the electrometer, after taking a ſpark from the ſtring, or preſenting the knob of a coated phial to it, riſes ſurpriſingly quick to its uſual place; but in dry and warm weather, it riſes exceeding ſlow.

Theſe few laws are, in ſhort, the deduction of all my experiments performed with the kites, during the courſe of about two years. How far they may be of uſe, or may coincide with the obſervations of other experimentators, I will not pretend to ſay. My experiments have been performed at Iſlington, and perhaps the reſult of ſimilar ones may be different at other places, eſpecially under different climates; I wiſh, therefore, that they may be accurately repeated in other places, and their reſult may be compared together; in order to determine, if poſſible, ſomething ſatisfactory, relative to the cauſe of that perpetual Electricity which exiſts in the atmoſphere, and which, very probably, occaſions the Electricity of the clouds.

CHAP. III.

Experiments performed with the Atmoſpherical Electrometer, and the Electrometer for the Rain.

FIG. 1. of Plate III. repreſents a very ſimple inſtrument, which I have contrived for the purpoſe of making obſervations on the Electricity of the atmoſphere; and which, on ſeveral accounts, ſeems to be the moſt uſeful for that purpoſe. A B is a common jointed fiſhing-rod, without the laſt or ſmalleſt joint. From the extremity of this rod proceeds a ſlender glaſs tube C, covered with ſealing-wax, and having a cork D, at its end, from which a pith-ball electrometer is ſuſpended. H G I is a piece of twine faſtened to the other extremity of the rod, and ſupported at G by a ſmall ſtring F G. At the end I of the twine a pin is faſtened, which, when puſhed into the cork D, renders the electrometer E uninſulated.

When I would obſerve the Electricity of the atmoſphere with this inſtrument, I thruſt the pin I into the cork D, and holding the rod by its lower end A, project it out from a window in the upper part of the houſe into the air, raiſing the end of the rod with the electrometer, ſo as to make an angle of about 50° or 60° with the horizon. In this ſituation I keep the inſtrument for a few ſeconds, and then pulling the twice at H, I diſengage the pin

from

from the cork D; which operation cauſes the ſtring to drop in the dotted ſituation K L, and leaves the electrometer inſulated and electrified, with an Electricity contrary to that of the atmoſphere.—This done, I draw the inſtrument into the room, and examine the quality of the Electricity, without obſtruction either from wind or darkneſs.

With this inſtrument I have made obſervations on the Electricity of the atmoſphere, ſeveral times in a day for ſeveral months, and from them I have deduced the following general obſervations, which ſeem to coincide with thoſe made with the electrical kites.

I. That there is in the atmoſphere, at all times, a quantity of Electricity; for, whenever I uſe the above-deſcribed inſtrument, it always acquires ſome Electricity.

II. That the Electricity of the atmoſphere, or fogs, is always of the ſame kind, namely poſitive; for the electrometer is always negative, except when it is evidently influenced by heavy clouds near the zenith; as appears by the obſervations made the 19th of October, in the following ſpecimen of the journal.

III. That in general, the ſtrongeſt Electricity is obſervable in thick fogs, and alſo in froſty weather; and the weakeſt, when it is cloudy, warm, and very near raining: but it does not ſeem to be leſs by night than in the day.

IV. That in a more elevated place the Electricity is ſtronger than in a lower one; for, having tried the atmoſpherical electrometer, both in the ſtone and iron gallery on the cupola of St. Paul's Cathedral, I found that the balls diverged much more in the latter than in the former leſs elevated place: hence it appears, that, if this rule takes place at any diſtance from the earth, the Electricity in the upper regions of the atmoſphere muſt be exceedingly ſtrong.

The following is the moſt remarkable part of the journal of the obſervations made with the above-deſcribed atmoſpherical electrometer, in which I have noted the Electricity of the electrometer, *i. e.* the contrary of that in the atmoſphere.

N. B. The ſtroke —— ſignifies *as above.*

Time of obſervation.	Clouds.	Fog.	Wind.	Opening of the electrometer in inches.	Quality of the Electricity.
October the 19th, 1776, ½ paſt 10 o'clock	Cloudy	Very little at a diſtance	Very ſtrong	$\frac{1}{10}$	Negative
11	——	——	——	——	——
2	Heavy clouds	——	Violent	$\frac{3}{4}$	Poſitive
½ paſt 2	Leſs clouds	——	Little	1	——
3	Few at a diſtance	——	——	$\frac{1}{2}$	Negative
November the 6th, 11 o'clock, P. M.		Exceedingly thick	o	1	——
November the 8th, 12 at noon	o	Hardly any	——	$\frac{1}{4}$	——
11	——	Very little	——	——	——
November the 13th, 10 o'clock, A. M.	Cloudy	Little at a diſtance	Pretty ſtrong	Very little	——
10 P. M.	——	o	——	$\frac{1}{4}$	——
November the 17th, 11 o'clock, P. M.	o	——	Violent	$\frac{1}{2}$	——
12	——	——	Very little	——	——
November the 28th, 10 o'clock, A. M.	——	——	Little	$\frac{1}{4}$	——
2	——	——	Hardly any	——	——
December the 20th, ½ paſt 9 o'clock, P. M.	Cloudy	Little	Very little	$\frac{1}{4}$	——
February the 6th, 1777, 2 o'clock, P. M.	——	o	——	$\frac{1}{4}$	——
February the 7th, 12 at noon	——	Little	——	$\frac{1}{4}$	——
8	o	Very little	Hardly any	$\frac{1}{4}$	——
February the 27th, 12 o'clock, P. M.	Few on the north	o	o	Very little	——
March the 28th, 11 o'clock, P. M.	o	——	——	$\frac{1}{10}$	——

The electrometer for the rain, in principle is nothing more than an inſulated inſtrument to catch the rain, and by a pith-ball electrometer to ſhew the quantity and quality of its Electricity.

Fig. 2. of Plate III. repreſents an inſtrument of this kind, which I have frequently uſed, and after ſeveral obſervations, have found to anſwer very well. A B C I is a ſtrong glaſs tube about two feet and a half long, having a tin funnel, D E, cemented to its extremity, which funnel defends part of the tube from the rain. The outſide ſurface of the tube from A to B is covered with ſealing-wax; ſo alſo is the part of it which is covered by the funnel. F D is a piece of cane, round which ſeveral braſs wires are twiſted in different directions, ſo as to catch the rain eaſily, and at the ſame time to make no reſiſtance to the wind. This piece of cane is fixed into the tube, and a ſlender wire proceeding from it goes through the bore of the tube, and communicates with the ſtrong wire A G, which is thruſt into a piece of cork faſtened to the end A of the tube. The end G of the wire A G is formed into a ring, from which I ſuſpend a more or leſs ſenſible pith-ball electrometer, as occaſion requires.

This inſtrument is faſtened to the ſide of the window-frame, where it is ſupported by ſtrong braſs hooks at C B, which part of the tube is covered with a ſilk lace, in order to adapt it better to the hooks. The part F C is out of the window, with the end F a little elevated above the horizon. The remaining part of the inſtrument comes through a hole in one of the lights of the ſaſh, within the room, and no more of it touches the ſide of the window than the part C B.

When it rains, eſpecially in paſſing ſhowers, this inſtrument, ſtanding in the ſituation above deſcribed, is frequently electrified; and, by the diverging of the electrometer, the quantity and quality of the Electricity of the rain may be obſerved, without any danger of a miſtake. With this inſtrument I have obſerved, that the rain is generally, though not always, electrified negatively, and ſometimes ſo ſtrongly ly that I have been able to charge a ſmall coated phial at the wire A G.

This inſtrument ſhould be fixed in ſuch a manner, that it may be eaſily taken off from the window, and replaced again, as occaſion requires; for it will be neceſſary to clean it very often, particularly when a ſhower of rain is approaching.

I ſhall conclude this chapter with the deſcription of a pocket electrometer, fig. 5 and 6. of Plate III. that I have lately conſtructed, and which, on ſeveral accounts, ſeems preferable to thoſe of the moſt ſenſible ſort now in uſe. The caſe, or handle of this electrometer is formed by a glaſs tube, about three inches long, and three-tenths of an inch in diameter, half of which is covered with ſealing-wax. From one extremity of this tube, *i. e.* that without ſealing-wax, a ſmall loop of ſilk proceeds, which ſerves occaſionally to hang the electrometer on a pin, &c. To the other extremity of the tube a cork is adapted, which, being cut tapering on both ends, can fit the mouth of the tube with either end. From one extremity of this cork, two linen threads proceed, a little ſhorter than the length of the tube, ſuſpending each a little *cone* of pith of elder. When this electrometer is to be uſed, that end of the cork which is oppoſite to the threads is puſhed into the mouth of the tube; then the tube forms the inſulated handle of the pith electrometer as repreſented fig. 6. Plate III. But when the electrometer is to be carried in the pocket, then the threads are put into the tube, and the cork ſtops it, as repreſented fig. 5. The peculiar advantages of this electrometer are, its convenient ſmall ſize, its great ſenſibility, and its continuing longer in good order than any other I have yet ſeen.

Fig. 4. of Plate III. repreſents a caſe to carry the above-deſcribed electrometer in. This caſe is like a common tooth-pick caſe, except that it has a piece of amber fixed on one extremity A, which may occaſionally ſerve to electrify the electrometer negatively, and on the other extremity it has a piece of ivory faſtened upon a piece of amber B C. This amber B C ſerves only to inſulate the ivory, which, when inſulated, and rubbed againſt woollen cloths, acquires a poſitive Electricity; and it is therefore uſeful to electrify the electrometer poſitively.

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CHAP. IV.

Experiments made with the Electrophorus, commonly called a Machine for exhibiting perpetual Electricity.

IN fig. 9. of Plate III. there are repreſented ſome Plates, commonly called the Machine for exhibiting perpetual Electricity, or the *Electrophorus.* This machine conſiſts of two plates, one of which, B, is a circular glaſs plate, covered on one ſide with ſome ſulphureous or reſinous electric, moſt commonly with a compoſition made of equal parts of roſin, ſhell-lac, and ſulphur; the other plate A, is a braſs plate, or a board covered with tin-foil, which is nearly of the ſame dimenſions as the electric plate, and it is furniſhed with a glaſs handle I, which, by means of a braſs or wooden ſocket, is ſcrewed into its center. This machine is the invention of an Italian philoſopher (Mr. VOLTA of Como) and its uſe is the following:

Firſt, the plate B is excited, by rubbing its coated ſide with a piece of new white flannel, and when excited as much as poſſible, is ſet upon the table with the coated ſide uppermoſt. Secondly, the metal plate is laid upon the excited electric, as repreſented in the figure. Thirdly, the metal plate, is touched with the finger or any other Conductor, which, on touching the plate, receives a ſpark from it. Laſtly, the metal plate A, being held by the extremity of its glaſs handle I, is ſeparated from the electric plate; and, after it is elevated above that plate, it will be found ſtrongly electrified, with an Electricity contrary to that of the electric plate, in which caſe it will give a very ſtrong ſpark to any Conductor brought near it. By ſetting the metal upon the electric plate, touching it with the finger, and ſeparating it ſucceſſively, a great number of ſparks may be

obtained

obtained apparently of the ſame ſtrength, and that without exciting again the electric plate. If theſe ſparks are repeatedly given to the knob of a coated phial, this will preſently become charged.

The action of theſe plates depends upon a principle long ago diſcovered, *viz.* the power that an excited electric has to induce a contrary Electricity in a body brought within its ſphere of action; the metal plate, therefore, when ſet upon the excited electric, acquires a contrary Electricity, by giving its electric fluid to the hand, or other Conductor that touches it, when ſet upon a plate poſitively electrified; or acquiring an additional quantity of fluid from the hand, &c. when ſet upon a plate electrified negatively.

As to the continuance of the virtue of this electric plate, when once excited, without repeating the excitation, I think there is not the leaſt foundation for believing it perpetual, as ſome perſons have ſuppoſed; it being nothing more than an excited electric, it muſt gradually loſe its power, by imparting continually ſome of its Electricity to the air, or other ſubſtances contiguous to it. Indeed its Electricity, although it could never be proved to be perpetual by experiments, laſts a very long time, it having been obſerved to be pretty ſtrong ſeveral days, and even weeks after excitation. The great duration of the Electricity of this plate, I think, depends upon two cauſes: firſt, becauſe it does not loſe any Electricity by the operation of putting the metal plate upon it, &c.; and ſecondly, becauſe of its flat figure, which expoſes it to a leſs quantity of air, in compariſon with a ſtick of ſealing-wax, or the like, which being cylindrical, expoſes its ſurface to a greater quantity of air, which is continually robbing the excited electrics of their virtue.

The firſt experiments that I made relative to this machine, were with a view to diſcover which ſubſtance would anſwer beſt for coating the glaſs plate, in order to produce the greateſt effect. I tried ſeveral ſubſtances either ſimple or mixed, and at laſt I obſerved, that the ſtrongeſt in power, as well as the eaſieſt I could conſtruct, were thoſe made with the ſecond ſort of ſealing-wax *, ſpread upon a thick plate of glaſs †. A plate that I made after this manner, and no more than ſix inches in diameter, when once excited, could charge a coated phial ſeveral times ſucceſſively, ſo ſtrong as to pierce a hole through a card with the diſcharge. Sometimes the metal plate, when ſeparated from it, was ſo ſtrongly electrified, that it darted ſtrong flaſhes to the table upon which the electric plate was laid, and even into the air, beſides cauſing the ſenſation of the ſpi-

der's

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* It is remarkable, that ſometimes they will not act well at firſt; but they may be rendered very good, by ſcraping with the edge of a knife the ſhining or gloſſy ſurface of the wax. This ſeems analogous to the well-known property of glaſs; which is, that new cylinders or globes, made for electrical purpoſes, are often very bad electrics at firſt, but that they improve by being worked, *i. e.* by having their ſurface a little worn. Paper alſo has this property.

† I have lately ſeen ſome of thoſe plates, conſtructed by Mr. G. ADAMS, which acted exceedingly well; and they were made with a compoſition of two parts of ſhell-lac, and one part of Venice turpentine, without any glaſs plate.

der's web upon the face brought near it, like an electric ſtrongly excited. The power of ſome of my plates is ſo ſtrong, that ſometimes the electric plate adheres to the metal, when this is lifted up; nor will they ſeparate, even if the metal plate is touched with the finger, or other Conductor.

If, after having excited the ſealing-wax, I lay the plate with the wax upon the table, and the glaſs uppermoſt, *i. e.* contrary to the common method, then, on making the uſual experiment of putting the metal plate on it, and taking the ſpark, &c. I obſerve it to be attended with the contrary Electricity; that is, if I lay the metal plate upon the electric one, and while in that ſituation touch it with an inſulated body, that body acquires the poſitive Electricity, and the metallic, removed from the electric plate, appears to be negative; whereas it would become poſitive if laid upon the excited wax. This experiment, I find, anſwers in the ſame manner, if an electric plate is uſed which has the ſealing-wax coating on both ſides, or one of Mr. ADAMS's, which has no glaſs plate.

If the braſs plate, after being ſeparated from, be preſented with the edge toward the wax, lightly touching it, and thus be drawn over its ſurface, I find that the Electricity of the metal is abſorbed by the ſealing-wax, and thus the electric plate loſes part of its power; and if this operation is repeated five or ſix times, the electric plate loſes its power intirely, ſo that a new excitation is neceſſary in order to revive it.

If, inſtead of laying the electric plate upon the table, it is placed upon an electric ſtand, ſo as to be accurately inſulated, then the metal plate ſet on it acquires ſo little Electricity that it can only be diſcovered with an electrometer; which ſhews, that the Electricity of this plate will not be conſpicuous on one ſide of it, if the oppoſite ſide is not at liberty either to part with, or acquire more of the electric fluid. In conſequence of this experiment, and in order to aſcertain how the oppoſite ſides of the electric plate would be affected in different circumſtances, I made the following experiments;

Upon an electric ſtand E, fig. 9. Plate III. I placed a circular tin plate, nearly ſix inches in diameter, which by a ſlender wire H communicated with an electrometer of pith-balls G, which was alſo inſulated upon the electric ſtand F. I then placed the excited electric plate D, of ſix inches and a quarter in diameter, upon the tin plate, with the wax uppermoſt, and on removing my hand from it, the electrometer G, which communicated with the tin plate, *i. e.* with the under ſide of the electric plate, immediately opened with negative Electricity. If, by touching the electrometer, I took that Electricity off, the electrometer did not afterwards diverge. But if now, or when the electrometer diverged, I preſented my hand open, or any other uninſulated Conductor, at the diſtance of about one or two inches, over the electric plate, without touching it, then the pith-balls diverged; or if they diverged before, came together, and immediately diverged again with poſitive Electricity;—I removed the hand, and the balls came together;—approached the hand, and they diverged; and ſo on.

If, while the pith-balls diverged with negative Electricity, I laid the metal plate, holding it by the extremity K of its glaſs handle, upon the wax, the balls came, for a little time, towards one another, but ſoon opened again with the ſame, *i. e.* negative Electricity.

If, whilſt the metallic reſted upon the electric plate, I touched the former, the electrometer immediately diverged with poſitive Electricity, which if, by touching the electrometer, I took off, the electrometer continued without divergence.—I touched the metal plate again, and the electrometer opened again; and ſo on for a conſiderable number of times, until the metal plate had acquired its full charge. On taking now the metal plate up, the electrometer G inſtantly diverged with ſtrong negative Electricity.

I repeated the above-deſcribed experiments with this only difference in the diſpoſition of the apparatus, *i. e.* I laid the electric plate D, with the excited ſealing-wax, upon the circular tin plate, and the glaſs uppermoſt; and the difference in their reſult was, that where the Electricity had been poſitive in the former diſpoſition of the apparatus, it now became negative, and *vice verſa*; except that, when I firſt laid the electric plate upon the tin, the electrometer G diverged with negative Electricity, as well in this as in the other diſpoſition of the apparatus.

I repeated all the above experiments with an electric plate, which, beſides the ſealing-wax coating on one ſide, had a ſtrong coat of varniſh on the other ſide; and their reſult was ſimilar to that of thoſe made with the above-deſcribed plate.

As to the explanation of theſe experiments, they ſeem to depend upon theſe two well-known principles, *viz.* that a body brought within the ſphere of action of an electrified body, does actually acquire the contrary Electricity; and that the exiſtence of one kind of Electricity upon the ſurface of a ſubſtance whatever, cauſes the exiſtence of the contrary Electricity upon ſome other ſubſtance near it.

CHAP. V.

Experiments on Colours.

HAVING accidentally obſerved that an electric ſhock, ſent over the ſurface of a card, marked a black ſtroke upon a red ſpot of the card, I was from this induced to try what would be the effect of ſending ſhocks over cards painted with different water-colours; accordingly, I painted ſeveral cards with almoſt every colour I had, and ſent ſhocks * over them, when they were very dry; making uſe of the univerſal diſcharger, fig. 5. Plate I. The effects were as follow:

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* The force generally employed was the full charge of one foot and a half of coated glaſs.

Vermilion was marked with a ſtrong black track, about one-tenth of an inch wide. This ſtroke is generally ſingle, as repreſented by A B, fig. 7. of Plate III; ſometimes it is divided in two towards the middle, like E F; and ſometimes, particularly when the wires are ſet very diſtant from one another, the ſtroke is not continued, but interrupted in the middle, like G H. It often, although not always, happens, that the impreſſion is marked ſtronger at the extremity of that wire from which the electric fluid iſſues, as it appears at E, ſuppoſing that the wire C communicates with the poſitive ſide of the jar; whereas the extremity of the ſtroke, contiguous to the point of the wire D, is neither ſo ſtrongly marked, nor ſurrounds the wire ſo much as the other extremity E.

Carmine received a faint and ſlender impreſſion of a purple colour.

Verdigriſe was ſhook off from the ſurface of the card, except when it had been mixed with ſtrong gum-water, in which caſe it received a very faint impreſſion.

White lead was marked with a ſtrong black track, not ſo broad as that on vermilion.

Red lead was marked with a faint mark, much like carmine.

The other colours I tried, were orpiment, gambodge, ſap-green, red-ink, ultramarine, Pruſſian blue, and a few others, which were compounds of the above; but they received no impreſſion.

It having been inſinuated, that the ſtrong black mark, which vermilion receives from the electric ſhock, might poſſibly be owing to the great quantity of ſulphur contained in the mineral, I was induced to make the following experiment :—I mixed together equal quantities of orpiment and flower of ſulphur, and with this mixture, by the help, as uſual, of very diluted gum-water, I painted a card; but the electric ſhock ſent over it left not the leaſt impreſſion.

Deſirous of carrying this inveſtigation on colours a little further, with a particular view to determine ſomething relative to the properties of lamp-black and oil *, I procured ſome pieces of paper painted on both ſides with oil colours, and, ſending the charge of two feet of coated glaſs over each of them, by making the interruption of the circuit upon their ſurfaces, I obſerved that the pieces of paper painted with lamp-black, Pruſſian-blue, vermilion, and purple brown, were torn by the exploſion, but white lead, Naples yellow, Engliſh ochre, and verdigriſe remained unhurt.

The ſame ſhock ſent over a piece of paper painted very thickly with lamp-black and oil left not the leaſt impreſſion. I ſent the ſhock alſo over a piece of paper un-

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* It has often been obſerved, that when the lightning has ſtruck the maſts of ſhips, it has paſſed over ſuch parts of the maſts which were covered with lamp-black and tar, or painted with lamp-black and oil, without the leaſt injury, at the ſame time that it has ſhivered the uncoated parts, in ſuch a manner as to render the maſts uſeleſs. For a particular account of ſuch facts, ſee the Phil. Tranſ. vol. XLVIII. and LXVII.

equally painted with purple brown, and the paper was torn where the paint laid very thin, but remained unhurt where the paint was evidently thicker. Theſe experiments I repeated ſeveral times, and with ſome little variation, which naturally produced different effects; however, they all ſeem to point out the following propoſition.

I. A coat of oil paint, over any ſubſtance, defends it from the effects of ſuch an electric ſhock, as would otherwiſe injure it; but by no means defends it from any electric ſhock whatever. II. No one colour ſeems preferable to the others, if they are equal in ſubſtance, and equally well mixed with oil; but a thick coating does certainly afford a better defence than a thinner one.

By rubbing the above-mentioned pieces of paper, I find that the paper painted with *lamp-black and oil* is more eaſily excited, and acquires a ſtronger Electricity, than the papers painted with the other colours; and perhaps on this account it may be, that lamp-black and oil might reſiſt the ſhock ſomewhat better than the other paints.

It is remarkable, that vermilion receives the black impreſſion, when painted with linſeed-oil, nearly as well as when painted with water. The paper painted with white lead and oil, receives alſo a black mark; but its nature is very ſingular. The track, when firſt made, is almoſt as dark as that marked on white lead, painted with water, but it gradually loſes its blackneſs, and in about one hour's time (or longer, if the paint is not freſh) it appears without any darkneſs; and when the painted paper is laid in a proper light, appears only marked with a colourleſs track, as if made by a finger-nail. I ſent the ſhock alſo over a piece of board, which had been painted with white lead and oil about four years before, and the exploſion marked the black track upon this alſo; this track however was not ſo ſtrong, nor vaniſhed ſo ſoon as that marked upon the painted paper, but in about two days time it alſo vaniſhed intirely.

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CHAP. VI.

Promiſcuous Experiments.

OBſerving that a ſtrong ſpark may be obtained from the metal plate belonging to Mr. Volta's machine, deſcribed in the fourth chapter of this Part, when not the leaſt ſpark can be obtained from the electric plate itſelf, I was naturally induced to make uſe of the above-mentioned metallic plate, to diſcover the Electricity of very weak electrics; which otherwiſe would be either inobſervable, or ſo ſmall as not to permit its quality to be aſcertained. Accordingly I conſtructed ſeveral ſuch plates of different ſizes, beginning from that of a common metal button faſtened upon a ſtick of ſealing-wax; and by uſing them, I obtained a very ſenſible Electricity from the hairs of my legs, when ſtroked, and of my head, or any part that I have tried of my body, or the head of almoſt any other perſon.

In this manner I obtain ſuch ſtrong ſparks from the back of a cat, a hare's ſkin, a rabbit's ſkin, a piece of flannel, or of paper, that I can preſently charge a coated phial with either of thoſe, and ſo ſtrongly, as to pierce a hole through a card with its diſcharge.

I have often obſerved that, when ſtroking a cat with one hand, and holding it with the other, I feel frequent ſmart prickings on different parts of that hand, which holds the animal. In theſe circumſtances very pungent ſparks may be drawn from the tips of the ears of the cat.

Smooth glaſs rubbed with a rabbit's ſkin, dry and warm, acquires, I find, the *negative* Electricity; but if the ſkin is cold, the glaſs is excited poſitively. Sometimes ſmooth glaſs may be excited negatively with new white flannel, clean and dry, and alſo with a hare's ſkin.

Obſerving the ſtrong electric power of new white flannel, I thought that a piece of it, rolled round the globe of an electrical machine, would perhaps give a ſtronger Electricity to the prime Conductor than the glaſs itſelf. In order to try the truth of my ſuppoſition, I tied a large piece of flannel, dry and warm, round the globe of the machine, and for a rubber, I applied the palm of my hand; then turned the winch, firſt ſlowly, and afterwards briſkly; but, contrary to my expectation, the Electricity at the prime Conductor, although poſitive, was ſo weak, that the index of the quadrant electrometer was not moved from its perpendicular ſituation. Surpriſed at this event, I reſolved to take off the apparatus; but I was more ſurpriſed, when, on removing the flannel from the globe, the former appeared ſo ſtrongly poſitive, that it darted ſeveral ſparks to my arm, and other contiguous bodies, and the latter remained ſo ſtrongly negative, that the electrometer upon the prime Conductor inſtantly elevated its index to about 45°. This experiment being ſeveral times repeated, produced always the ſame effect.

Having had occaſion to coat a ten ounce phial for the Leyden experiment, I ſtuck the braſs filings on the inſide of it with varniſh, agreeable to the directions given by ſome writers on Electricity. This phial remained about a week unuſed, but it happened that whilſt I was charging and diſcharging it for ſome experiments, on making a diſcharge, it exploded with a greater noiſe than uſual, the cork with the wire being at the ſame time blown out of the neck of it. Being intent upon the main experiments in hand, I omitted to examine this phenomenon;—I replaced the cork into the neck of the phial, and went on charging and diſcharging it again; but it had not been charged above three or four times more, when, on making a diſcharge, the varniſh that ſtuck the braſs filings was in a flame, which burnt the under ſide of the cork, and occaſioned a good deal of ſmoke and flame to come out of the phial. Some days after, this experiment was repeated in the preſence of three gentlemen, well verſed in Electricity, when the cork with the wire was alſo puſhed out of the neck of the phial; but the varniſh was this laſt time ſo far burnt, that the braſs filings were almoſt all dropped to the bottom of the phial, and had their colour changed by the combuſtion.

In making ſome experiments, of a nature rather different from Electricity, I accidentally obſerved, that when I agitated ſome quickſilver in a glaſs tube, hermetically ſealed, and in whoſe cavity the air was very much rarefied, the outſide of the tube appeared ſenſibly electrified; its Electricity however was not conſtant, nor, as I firſt thought, in proportion to the agitation of the quickſilver. Being deſirous of aſcertaining the properties of ſuch tubes, I conſtructed ſeveral of them, and by means of two cork-ball electrometers, obſerved their properties; but as they all agree in regard to the chief points, I ſhall only deſcribe one, which is the beſt of them. This tube is repreſented by fig. 3. of Plate III. Its length is thirty-one inches, and its diameter is little leſs than half an inch. The quickſilver in it may be about three-fourths of an ounce; and in order to exhauſt it of air, I cloſed it while the quickſilver was boiling in its oppoſite end.

Before this tube is uſed, I make it a little warm, and clean it; then holding it nearly horizontal, I let the quickſilver in it run from one end of the tube to the other, by gently and alternately elevating and depreſſing its extremities. This operation immediately renders the outſide of the tube electrical, but with the following remarkable property, *viz.* that end of the tube, where the quickſilver actually ſtands, is poſitive, and all the remaining part is negative. If by elevating this poſitive end of the tube a little, I let the quickſilver run to the oppoſite end, which was negative, then the former inſtantly becomes negative, and the latter poſitive. The poſitive end has always a ſtronger Electricity than the negative. If when one end of the tube, for inſtance A, is poſitive, *i. e.* when the quickſilver is in it, I do not take off that Electricity by touching it; then on elevating this end A, ſo as to let the quickſilver run to the oppoſite end B, it appears negatively electrified in a very ſmall degree. If by depreſſing it again it be rendered poſitive a ſecond time, and that poſitive Electricity is neither taken off, then on elevating this end A again, it appears to be poſitive in a ſmall degree: but if whilſt it is poſitive, its Electricity be taken off, then on being elevated, it appears ſtrongly negative.

When about two inches of each extremity of this tube is coated with tin-foil as it appears in the figure, that coating aſſiſts to render the Electricities at the extremities of the tube more conſpicuous, ſo that ſometimes they give ſparks to a Conductor brought near.

In regard to the conſtruction of ſuch tubes (which I have made of ſeveral lengths, from nine to thirty-one inches) it is obſervable, that ſome will act very well, while others will hardly acquire any Electricity at all, even when they are made very hot. I am not yet thoroughly ſatisfied in reſpect to this difference, but ſuſpect that the thickneſs of the glaſs is more concerned, than any thing elſe; it appearing that a tube, whoſe glaſs is about one-twentieth of an inch thick, anſwers better than either a thicker or a thinner one.

The following Chapter contains the account of ſome experiments, which I made ſince the firſt publication of this Book; for which reaſon, I deemed proper to relate them apart, without altering the preceding chapters, with the contents of which they are however connected.

CHAP. VII.

An Account of ſome new Experiments in Electricity, with the Deſcription and Uſe of two new Electrical Inſtruments.

PRofeſſor LICHTENBERG of Gottingen, ſome time ago made an experiment upon the electrophorus, an account of which was firſt received in London towards the latter end of the year 1777. The phenomena attending the experiment are very entertaining and various, but I do not know that any perſon ever offered a ſatisfactory explanation of them. The author himſelf, in his paper entitled "*De nova methodo naturam ac motum fluidi electrici inveſtigandi Commentatio prior,*" wherein in he gives an account of the experiment, does not attempt any explanation of it; contenting himſelf with the account only of various particulars attending it.—In brief, the experiment is as follows:

The electrophorus, that is, a plate of ſome reſinous ſubſtance, as ſulphur, roſin, gum-lac, &c. is firſt excited, either by rubbing or otherwiſe; then a piece of metal of any ſhape, at pleaſure, as for inſtance, a three-legged compaſs, a piece of braſs tube, or the like, is ſet upon the electrophorus, and to this piece of metal ſo placed, a ſpark is given, of the Electricity contrary to that of the plate; this done, the piece of metal is removed, by means of a ſtick of ſealing-wax or other electric, and ſome powder of roſin, kept in a linen bag, is ſhaken upon the electrophorus: this powder will be found to fall about thoſe points upon the plate, which the piece of metal touched, forming ſome radiated appearances, much like the common repreſentations of ſtars; at the ſame time, upon the greateſt part of the plate, that is, beſides thoſe ſtars, there is hardly any powder at all. Now, it is to be remarked, that if the plate is excited negatively, and the ſpark given to the metal ſet upon it is poſitive, the appearance will be as above-deſcribed; but if, on the contrary, the plate is poſitive and the ſpark is negative, then the powder of roſin will be found to fall upon thoſe parts of the plate which in the other caſe it left uncovered, and to leave the ſtars clean; in ſhort, it will do juſt the reverſe of what it did in the other caſe; or, in other words, the powder of roſin will be attracted by thoſe parts only of the electrophorus which are electrified poſitively.

When I firſt obſerved theſe phenomena, I thought there was no apparent reaſon why the powder of roſin ſhould be attracted by thoſe parts of the electrophorus which are poſitively electrified, and not by thoſe which are negative. The two Electricities are certainly contrary to one another; but either of them attracts a non-electrified body. Inſiſting upon this conſideration, I thought that the experiment could be explained only upon the ſuppoſition, that the powder of roſin, on its falling from the linen bag, was actually electrified negatively; in which caſe it would have been eaſy to account for the phenomena upon the well-known principle of bodies contrarily electrified attracting each other, and repelling one another when poſſeſſed of the ſame kind of Electricity.

In order to try the reality of my ſuppoſition by experiments, I inſulated a braſs plate upon a glaſs ſtand, and connected a very ſenſible electrometer with it; then began ſhaking the powder of roſin upon it, in the ſame manner as I had done upon the electrophorus, and in a few ſeconds time had the pleaſure to ſee the electrometer diverge with a very manifeſt degree of negative Electricity, anſwering my expectations exactly. The explanation of the ingenious Profeſſor LICHTENBERG's experiment, now became very eaſy and natural; for the powder of roſin being actually electrified negatively, could not be attracted, except by thoſe parts of the electrophorus which are in a contrary ſtate, *i. e.* electrified poſitively. It is obſerved, that powder of roſin anſwers better for this experiment than the powders of other ſubſtances; and accordingly I find that this powder, when ſhaken upon the inſulated braſs plate, ſhews a ſtronger degree of Electricity than the other powders. Indeed the Electricity of the powder of roſin, not only when ſhaken upon the braſs plate in the manner abovementioned, but ſimply let fall upon it from a piece of paper, a ſpoon, &c. is very great; half an ounce of this powder being ſufficient to let the threads of the electrometer diverge as much as they poſſibly can.

This diſcovery not only affords an eaſy explanation of Profeſſor LICHTENBERG's experiment upon the electrophorus, but ſhews a method of exciting powders, which has long been a deſideratum in the ſcience of Electricity. The method is as follows:— Inſulate a metal plate upon an electric ſtand, and connect with it a cork-ball-electrometer; then the powder required to be tried, being held in a ſpoon, or other thing, at about ſix inches above the plate, is to be let fall gradually upon it. In this manner the Electricity acquired by the powder, being communicated to the metal plate, and to the electrometer, is rendered manifeſt by the divergence of the threads; and its quality may be aſcertained in the uſual manner. See fig. the 4th of Plate IV.

It muſt be obſerved, that if the powder is of a conducting nature, like the amalgam of metals, ſand, &c. it muſt be held in ſome electric ſubſtance, as a glaſs phial, a plate of ſealing-wax, or the like. Sometimes the ſpoon that holds the powder may be inſulated; in which caſe, after the experiment, the ſpoon will be found poſſeſſed of an Electricity contrary to that of the powder.

In performing theſe experiments care muſt be had to render the powders, and whatever they are held in, as free from moiſture as poſſible; ſometimes it being neceſſary to make them very warm, otherwiſe the experiment is apt to fail. The following are the particulars that I have obſerved with this new method, which however are neither numerous, nor often repeated; but they may ſuffice to excite the curioſity of thoſe perſons, who have leiſure and the opportunity of repeating them more at large and in a greater variety.

Powder of roſin, whether it be let fall from paper, glaſs, or a metal ſpoon, electrifies the plate ſtrongly negative; the ſpoon, if inſulated, remaining ſtrongly poſitive. Flower of ſulphur produces the ſame effect, but in a little leſs degree. Pounded glaſs, let fall from a piece of paper, made dry and warm, electrifies the plate negatively, but not in ſo ſtrong a degree as roſin. If it is let fall from a braſs cup, it electrifies the plate poſitively, but in a very ſmall degree.

Steel-filings let fall either from a glaſs phial or paper, electrify the plate negatively; but braſs-filings, treated in the ſame manner, electrify the plate poſitively. The amalgam of tin-foil and mercury, gunpowder, or very fine emery, electrify the plate negatively, when they are let fall upon it from a glaſs phial. Quickſilver, from a glaſs phial, electrifies the plate poſitively.

Soot from the chimney, or the aſhes of common pit-coals mixed with ſmall cinders, electrify the plate negatively, when let fall from a piece of paper.

Deſcription of the improved atmoſpherical Electrometer.

Fig. the 2d of the annexed drawing is a geometrical repreſentation of my new atmoſpherical electrometer, in its real ſize; this inſtrument, whoſe firſt hint I received from my friend T. RONAYNE, Eſq; after various trials, I brought to the preſent ſtate of perfection, as long ago as the year 1777; and immediately after, ſeveral of them were made after my pattern by Mr. ADAMS, philoſophical inſtrument maker, in Fleet Street. The great difficulty attending the conſtruction of this inſtrument, has long diſſuaded my publiſhing any deſcription of it; nor had I ever troubled the Royal Society with it, if the obſervations of ſeveral of my friends, who have uſed it in England and abroad, joined to my own repeated experiments, had not indiſputably confirmed its ſuperiority to any other inſtrument of that kind. Its particular advantages are: I. The ſmallneſs of the ſize; II. Its being always ready for experiments, without fear of entangling the threads, or having an equivocal reſult by the ſluggiſhneſs of its motion; III. Its being not diſturbed by wind or rain; IV. Its great ſenſibility; and V. Its keeping the communicated Electricity longer than any other electrometer.

The principal part of this inſtrument is a glaſs tube C D M N, cemented at the bottom into the wooden piece A B, by which part the inſtrument is to be held when uſed for the atmoſphere; and it alſo ſerves to ſcrew the inſtrument into its wooden caſe A B O, fig. 1. when it is not to be uſed *. The upper part of the tube C D M N, is ſhaped tapering to a ſmaller extremity, which is entirely covered with ſealing-wax, melted by heat, and not diſ-

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* The whole caſe of this electrometer has been made alſo of braſs, and has been found to anſwer better than wood, as it does not warp.

ſolved by ſpirits. Into this tapering part a ſmall tube is cemented, the lower extremity G of which being alſo covered with ſealing-wax, projects a ſhort way within the tube C D M N. Into this ſmaller tube a wire is cemented, which with its under extremity touches the flat piece of ivory H, faſtened to the tube by means of cork; the upper extremity of the wire projects about a quarter of an inch above the tube, and ſcrews into the braſs cap E F, which cap is open at the bottom, and ſerves to defend the waxed part of the inſtrument from the rain, &c. In fig. 3. this braſs cap is repreſented as tranſparent, in order to ſhew its internal ſhape, and the manner in which it is ſcrewed to the wire projecting above the tube L. The ſmall tube L, and the upper extremity of the large tube C D M N, appear like one continued piece, on account of the ſealing-wax, which covers them both. The conical corks P of this electrometer, which by their repulſion ſhew the Electricity, &c. are as ſmall as they can poſſibly be made, and they are ſuſpended by exceedingly fin ſilver wires; theſe wires are ſhaped in a ring at the top, by which they hang very looſely to the flat piece of ivory H, which has two holes for that purpoſe. By this method of ſuſpenſion, which is applicable to every ſort of electrometer, the friction is leſſened almoſt to nothing, and thence the inſtrument is ſenſible of a very ſmall degree of Electricity. I M, and K N, are two narrow ſlips of tin-foil, ſtuck to the inſide of the glaſs C D M N, and communicating with the wooden bottom A B;—they ſerve to convey off that Electricity, which, when the corks touch the glaſs, is communicated to it, and being accumulated might diſturb the free motion of the corks.

In regard to its uſe, this inſtrument may ſerve to obſerve the artificial, as well as the atmoſpherical Electricity. When it is to be uſed for artificial Electricity, this electrometer is ſet upon a table or other convenient ſupport, then it is electrified by touching the braſs cap E F with an electrified body, which Electricity will ſometimes be preſerved for more than an hour *; in this ſtate, if any electrified ſubſtance is brought near the cap E F, the corks of the electrometer, by their converging or diverging more, will ſhew the ſpecies of that body's Electricity.

Before we proceed, it is neceſſary to remark, that to communicate any Electricity to this electrometer, by means of an excited electric, *e. g.* a piece of ſealing-wax (which we ſuppoſe as always negatively electrified) is not very readily done in the uſual manner, becauſe of the cap E F being well rounded, and free from points or ſharp edges. By the approach of the wax, the electrometer will be cauſed to diverge; but as ſoon as the wax is removed, the wires immediately collapſe. The beſt method to electrify it, is to bring the excited wax ſo near the cap, that one or both the corks may touch the ſide of the bottle C D M N; after which, they will ſoon collapſe and appear unelectrified; if now the wax is removed, they will again diverge, and remain electrified poſitively.

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* I once made an electrometer of this ſort, which could continue to be electrified for above 12 hours, and that in a room without fire.

In this operation, the wax does not impart any of its Electricity to the electrometer, but only act by means of its atmoſphere, *viz.* when the excited wax is firſt brought near the braſs cap E F, (agreeable to the well-known law of Electricity, and according to Dr. FRANKLIN's hypotheſis) it determines the electric fluid naturally belonging to the corks towards the cap; hence the corks repel each other. Now, if in this ſtate they touch the ſides of the glaſs C D M N, they acquire from it a quantity of electric fluid equal to that which, by the action of the excited wax, was driven towards the cap; conſequently they collapſe, and appear unelectrified. Notwithſtanding this appearance, the cap is actually overcharged; ſo that when the wax is removed, the overplus of the electric fluid, which the corks had acquired from the glaſs and tin-foil ſtuck upon it, and which was crowded upon the cap, becauſe of the negative atmoſphere of the wax, now diffuſes itſelf equally through the cap, the wires, the corks, &c. and therefore the corks repel each other with poſitive Electricity.

If, inſtead of the ſealing-wax excited negatively, an electric poſſeſſed of poſitive Electricity be uſed, the electrometer acquires the negative Electricity, and the explanation, *mutatis mutandis*, is the ſame as above.

By conſidering this remark it will appear, that when this electrometer is electrified either poſitively or negatively, and an electrified body be brought towards the braſs cap, the Electricity of that body will be of the ſame kind with that of the electrometer if the corks increaſe their divergency; but it will be of the contrary kind if the corks approach one another.

When this inſtrument is to be uſed to try the Electricity of the fogs, the air, the clouds, &c. the obſerver is to do nothing more than to unſcrew it from its caſe, and, holding it by the bottom A B, to preſent it to the open air, a little above his head, ſo that he may conveniently ſee the corks P, which will immediately diverge if there is any Electricity; whoſe nature, *i. e.* whether poſitive or negative, may be aſcertained by bringing an excited piece of ſealing-wax, or other electric, towards the braſs cap E F.

It is perhaps unneceſſary to remark, that this obſervation muſt be made in an open place, as the roads out of town, the fields, the top of a houſe, &c.

In the roads between Iſlington and London, I have often made uſe of this inſtrument; by which I have confirmed the obſervations of THOMAS RONAYNE, Eſq; who firſt diſcovered the Electricity of the fogs, as teſtified by a paper of his publiſhed in the Phil. Tranſactions; and who has remarked, that a fog is very rarely not electrified, but in froſty weather the air is conſtantly electrified.

Promiſcuous Experiments.

Having had frequent occaſion to obſerve how difficult it is to deprive ſealing-wax of its Electricity entirely, after it has been well excited, I had the curioſity to try whether water could effect it; in order to that, I tied a ſtick of ſealing-wax to a ſilk ſtring, about a yard long, and after having excited it very powerfully with flannel, I plunged it in a tin veſſel full of water, and immediately drawing it out, brought a very ſenſible electrometer near it, and obſerved, that at firſt it ſhewed no ſign of Electricity, but in about half a minute's time it manifeſted a ſmall, but very ſenſible degree of negative Electricity. A glaſs tube treated in the ſame manner, was deprived of all its Electricity by the water.

I have often remarked, that after having excited a glaſs tube with the amalgamed rubber, in the uſual manner, the part of it which had been under my hand, was negative. This minus ſtate was ſtill more conſpicuous, when I graſped with my hand the part next above, *viz.* part of that which had been excited poſitively by rubbing. In the ſame manner, when I excite a ſtick of ſealing-wax by rubbing it with flannel, I often find, that the part of it which I had held with my hand was in a contrary ſtate of Electricity, *viz.* poſitive.

Being deſirous of trying the conducting power of the effluvia of burning bodies, in a manner more ſatisfactory than it had hitherto been done, I contrived an inſtrument for that purpoſe, which is repreſented in fig. 5 *. The handle of it A B, is a glaſs tube, into the extremity B of which, a wire E I, and a ſmaller glaſs tube B C, are cemented by means of ſealing-wax. From the extremity of this ſmall tube, another wire G F proceeds, which, as well as the wire E I, is bent at top, ſo that the extremities of both wires E F may be about one-tenth of an inch from one another. G H is a ſmall wire, faſtened to the wire F G, and to the extremity of the handle, ſo that when the inſtrument is held in one's hand, this wire touches the hand. K is a ſmall cork-ball electrometer, which, when the inſtrument is to be uſed, is affixed to the pin D, which proceeds from the wire I E. When experiments are to be tried with this inſtrument, the electrometer K muſt be affixed to the pin D, and muſt be electrified ſo as the cork-balls may diverge as far as poſſible: this done, the extremities E F of the wires are brought within the effluvia that are to be tried, which, if they are of a good conducting nature, will complete the communication between the two wires E F, and diſcharge the electrometer of its Electricity; otherwiſe the electrometer will remain electrified for a conſiderable time. The experiments which I made with this inſtrument are neither numerous, nor ſo often repeated as to be depended upon; excepting one only, which perhaps it will not be uſeleſs to mention: I found that the fumes ariſing by the action of a lens from the amalgam of tin-foil and mercury, conducted ſo badly, that the electrometer loſt its Electricity in a time very little leſs, than is required without any fumes whatever.

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* This fig. is half the real ſize of the inſtrument.

APPENDIX.

APPENDIX.

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N° I.

OF THE VINDICATING ELECTRICITY.

1. AB, *ab*, fig. 6, repreſents a plate of glaſs, coated on both ſides with the two metallic coatings C D, *c d*, which are not ſtuck to the glaſs plate, but are only laid upon it.

From the upper coating C D, three ſilk threads proceed, which are united at their top H, by which the ſaid coating may be removed from the plate in an inſulated manner, and may be preſented to an electrified electrometer, as repreſented in fig. 7, in order to examine its Electricity. F G is a glaſs ſtand, which inſulates and ſupports the plate, &c.

2. Let the plate A B, *ab*, be charged in the common manner, by means of an electrical machine, ſo that its ſurface A B may acquire one kind of Electricity, (which may be called K) and the oppoſite ſurface *a b* may acquire the contrary Electricity, (which we ſhall call L). Then, if the coating C D be removed from the plate, and be preſented to an electrified electrometer, as repreſented in fig. 2. it will be found poſſeſſed of the Electricity K, *viz.* of the ſame kind with that which was communicated to the ſurface A B of the glaſs plate; from whence it is deduced, that the ſurface A B has imparted ſome of its Electricity to the coating. Now, this diſpoſition of the charged plate to give part of its Electricity to the coating, is what the learned F. BECCARIA nominates the *Negative vindicating Electricity*.

3. If the coating be again and again alternately laid upon the plate and removed, its Electricity K, will be found to decreaſe gradually, 'till after a number of times (which is greater or leſs, according as the edges of the plate inſulate more or

leſs exactly) the coating will not appear at all electrified. This ſtate is called *the limit of the two contrary Electricities*; for if now the above-mentioned operation of coating and uncoating the plate be continued, the coating will be found poſſeſſed of the contrary Electricity, *viz.* the Electricity L. This Electricity L. of the coating is weak on its firſt appearance, but it gradually grows ſtronger and ſtronger till a certain degree; then inſenſibly decreaſes, and continues decreaſing until the glaſs plate has entirely loſt every ſign of Electricity.

By this change of Electricity in the coating, it is deduced, that the ſurface A B of the glaſs plate changes property; and whereas at firſt it was diſpoſed to part with its Electricity, now (*viz.* beyond *the limit of the two contrary Electricities*) it ſeems to *vindicate* its own property, that is, to take from the coating ſome Electricity of the ſame kind with that of which it was charged: hence this diſpoſition was by F. BECCARIA called the *Poſitive vindicating Electricity*.

4. This poſitive vindicating Electricity never changes, though the coating be touched every time it is removed. It appears ſtronger, and laſts a very conſiderable time after the plate has been diſcharged; which is a very ſurpriſing property of glaſs, and probably of all good and ſolid electrics.

5. If, ſoon after the diſcharge of the plate, the coating be alternately taken from the plate, and replaced, but with the following law, *viz.* that when the coating is upon the plate, both coatings be touched at the ſame time, and when the coating is off, this be either touched or not; then the ſurface A B of the plate, on being uncoated every time, takes a quantity of Electricity, which it alternately loſes every time it is coated *.

6. On removing the coating in a dark room, a flaſh of light appears between it and the glaſs, which is ſtill more conſpicuous,

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* This may be proved by touching an inſulated electrometer with the coating, when this is ſtanding upon the plate, and when ſeparated from it.

cuous, if the coating be removed by the fingers being applied immediately to it, *viz.* not in an inſulated manner; becauſe, when the coating is not inſulated, the glaſs plate can give to, or receive from it, more of the electric fluid, and that more freely, than otherwiſe.

7. It is obſervable, that in the negative vindicating Electricity, the glaſs loſes a greater or leſs portion of Electricity, in an inverſe proportion of the charge given to the plate, *viz.* the part loſt is greater when the charge has been the weaker; for in the poſitive vindicating Electricity, the force of receiving Electricity is the ſtronger, when the charge has been ſtronger, and contrarywiſe.

8. If, after every time that the coating CD is removed, the atmoſpheres E, *e*, that is, the air contiguous to the ſurface of the glaſs plate, be examined, they will be found electrified as in the following table, *viz.* the threads of an electrometer, brought within one or two inches, or more, of the ſurfaces A B, *ab*, will diverge with Elec-

tricities contrary to thoſe expreſſed in the table.

During the time of the negative vindicating Electricity	the air E, if the plate has been charged	moderately high - - very high -	moderately L o moderately K
	the air *e* is electrified L.		

During the time of the poſitive vindicating Electricity	the air E The air *e*	are electrified L.

9. Although we are not acquainted with the cauſe of vindicating Electricity, any farther than to conſider it as a diſpoſition or property of charged glaſs, yet the phenomena of the Electricities of the air, contiguous to the ſurfaces of the plate, ſeem to be a proper conſequence of Dr. FRANKLIN's theory of Electricity, and are accountable by it; for it is a well-known principle of that theory, that when one ſide of a coated electric, fit to receive a charge, acquires a greater quantity of Electricity than the oppoſite ſide can acquire of the contrary Electricity, then both ſides of that electric appear poſſeſſed of the ſame kind of Electricity, namely, of that com-

municated to the firſt-mentioned ſide. Now, when in the negative vindicating Electricity, the ſurface A B of the glaſs plate gives part of its Electricity to the coating; then the other ſide *ab*, being more electrified L, than the ſide A B is electrified K, it is plain that, according to the ſaid principle, both ſides muſt appear electrified L. But in the poſitive vindicating Electricity, the ſide A B of the glaſs plate receives ſome Electricity of the kind K from the coating, therefore both ſides muſt affect the air with the Electricity K.

10. There remains only to be explained the reaſon why, when the plate has received a high charge, the air E, during the time of the negative vindicating Electricity, appears electrified K, whilſt the air *e* is electrified L. In order to render this explanation more intelligible, let us ſuppoſe the glaſs plate to have been electrified poſitively on the ſide A B; then, in the negative vindicating Electricity, the ſurface A B, on being uncoated, loſes a part of its Electricity, which is ſo much the greater as the charge has been the leſs (§ 7.);

therefore,

therefore, when the charge has been moderate, A B loſes a greater portion of electric fluid, than that with which the air *e* can ſupply the ſurface *ab*; hence the ſurface *ab* will remain more negatively electrified than the ſurface A B is poſitively; conſequently, according to the above-mentioned principle, (§ 9.) both the atmoſpheres E, *e*, muſt appear in a negative ſtate when the charge has been a certain degree higher; then the ſurface A B, on being uncoated, loſes juſt ſo much of the electric fluid as the air *e* can give to *ab*, therefore the air will not appear electrified. But when the charge has been very high, A B loſes a leſs portion of electric fluid than the air *e* can give to *ab*; therefore *e*, by having given ſome of its natural electric fluid to *ab*, will appear negative, and E will appear poſitive in a ſmall degree. If the plate be ſuppoſed to have been charged negatively on the ſide A B, the explanation of the phenomena is the ſame, changing only the name of poſitive Electricity into negative, &c.

11. This property of charged glaſs, called vindicating Electricity, is obſervable

alſo when two glaſs plates, laid one over the other, and coated on their outward ſurfaces only, are charged jointly like one plate. Suppoſe A B, C D, fig. 8, to repreſent the two plates charged together, *viz.* by having preſented the coating F to the prime Conductor, and having at the ſame time connected the coating G with the ground, in which ſtate, it is eaſy to conceive, that the upper ſurface of the plate A B would be poſitive, its under ſurface would be negative, the upper ſurface of the plate C D, *viz.* the ſurface contiguous to the plate A B, would be poſitive, and its oppoſite ſurface G would be negative. Now if theſe plates, after having been charged, be alternately ſeparated and joined, without ever touching their coatings, it is plain that their ſurfaces, contiguous to one another, whenever the plates are ſeparated, will uncoat each other, conſequently the phenomena of vindicating Electricity will take place, that is, each of the inſide or naked ſurfaces, when the plates are firſt ſeparated, will loſe part of its Electricity. This loſt Electricity gradually decreaſes till it vaniſhes, after which period, each of the ſaid ſurfaces will gradually recover part of its loſt Electricity, &c.

12. By the principle noticed above, (§ 9.) when one ſurface of either plate has acquired a quantity of one kind of Electricity more than the oppoſite ſurface has acquired of the other, then both ſurfaces of that plate muſt appear poſſeſſed of that and the ſame kind of Electricity; hence it follows, that when the plates A B, C D, are at firſt ſeparted for a certain number of times, *i. e.* during the negative vindicating Electricity, the plate A B muſt appear poſitive on both ſides, and the plate C D negative on both ſides; but after the *limit of the two contrary Electricities*, when the poſitive vindicating Electricity has taken place, then the plate A B will appear negative on both ſides, and the plate C D poſitive on both ſides.

13. The adherence of the plates to one another keeps pace with the vindicating Electricity; ſo that it is very ſtrong at firſt, but gradually decreaſes with the negative vindicating Electricity, till it becomes inſenſible;

ſenſible; but after the limit of the two contrary Electricities it appears again, and then it increaſes and decreaſes with the poſitive vindicating Electricity.

14. Every other particular relating to the phenomena of vindicating Electricity, exhibited with one plate, does alſo take place in the experiment with two plates; except the phenomena conſidered above (§ 10.), which the two plates cannot exhibit, on account that they are not capable of receiving a very high charge, as a ſingle plate is; which high charge is abſolutely neceſſary to produce that appearance.

N° II.

OBSERVATIONS UPON THE CONDUCTORS OF LIGHTNING.

SINCE the publication of the Firſt Edition of this Treatiſe, it happened that a houſe belonging to the Board of Ordnance, at Purfleet, was ſtruck by lightning, though furniſhed with a Conductor. This accident excited anew the controverſy relating to the conſtruction of Conductors to ſecure houſes from the effects of lightning, eſpecially relating to their termination; and various experiments were made by very able Electricians, in order to decide the controverted point. Mr. B. WILSON and Mr. ED. NAIRNE, both members of the Royal Society, were the principal actors in this experimental inveſtigation; the former giving conſtantly the preference to ſhort conductors terminating in a ball, and the latter preferring long Conductors acutely pointed; which has been and is the prevailing opinion with almoſt all the principal Electricians in England, as well as abroad; beginning from the firſt inventor of thoſe Conductors (the great philoſopher Doctor FRANKLIN). Mr. WILSON, the principal and almoſt the ſole opponent of the Franklinian conſtruction of Conductors, exhibited ſome ingenious electrical experiments upon a large ſcale; which threw great light upon the property of points in reſpect to Electricity, and ſeem at firſt ſight to decide the queſtion in favour of knobbed Conductors, as will appear by the following pages. On the other ſide, Mr. NAIRNE performed ſome well-imagined experiments, which ſeem to eſtabliſh, beyond any doubt, the prevailing opinion in favour of pointed Conductors; which was afterwards ſtill more confirmed and elucidated by Lord MAHON, in his learned work, entitled, *Principles of Electricity*, and publiſhed in the year 1779.

Notwithſtanding thoſe various diſquiſitions, and new obſervations, it ſeems that what I had previouſly wrote, relating to the conſtruction of Conductors, did not require any material alteration; hence I thought proper to reprint, in this Second

Edition, exactly that which had been advanced relating to Conductors of lightning in my firſt publication; and have reſerved for this diſſertation, to make mention of thoſe additional remarks, which, in the preſent more advanced ſtate of the ſcience, are neceſſary to be noticed. Mr. Wilson, Mr. Nairne, and others, muſt excuſe my giving a very ſhort and ſummary account of their valuable experiments, ſince the limits of this work are by far too ſhort to admit a full account of their obſervations. I ſhall juſt mention the principal facts aſcertained, ſo as to make evident the deduction which naturally follows them, and which is neceſſary to eſtabliſh the preſent improved theory of Conductors; omitting thoſe remarks which ſeem to be not eſſential, and even diſpenſing with the particular deſcription of the various apparatuſes uſed for this purpoſe. The *Board-houſe*, ſtruck by lightning on the 12th of May 1777, had a pointed iron ſpike, which projected ten feet above the middlemoſt and higheſt part of its roof, and which had a continued metallic communication to the ground. The lightning did no other damage to his houſe, than to throw down a few ſtones from one of its upper corners, which were next to two iron cramps; which cramps had not a metallic communication with the Conductor. This corner was forty-ſix feet diſtant from the top of the Conductor. In this caſe it is difficult to ſay, whether the lightning ſtruck the Conductor firſt, or the corner of the houſe juſt over the above-mentioned iron cramps, and from thence, being paſſed to the metal which communicated with the Conductor, was conducted to the ground, without cauſing any farther damage to the houſe. In the firſt caſe, the point of the Conductor would, in all probability, have been fuſed, as is generally the caſe; but no mark of fuſion could be perceived on it. The ſecond caſe ſeems not very likely to have happened, ſince the Conductor was far above the corner that was ſtruck, and ſince the lightning is known to ſtrike the moſt elevated objects, and thoſe which have a better communication with the earth, in preference to any other *. In any caſe, the

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* Mr. Nairne terminates the account of his above-mentioned experiments with the following paſſage;

"I muſt

the only uſeful remark that can be drawn from this accident is, that all the metallic parts, that are in a building, ſhould be connected with the Conductor, otherwiſe it is not unlikely, but that, either by a direct ſtroke, or by a lateral exploſion, the houſe may ſuffer ſome damage from lightning. Mr. **Wilson**, who had formerly declared his opinion againſt elevated and pointed Conductors, derived from this accident a ſtrong proof apparently in favour of his theory,

"I muſt beg to intrude a little more on your time, "to remark on that part of Mr. **Wilson**'s paper, "where, from his experiments, he ſeems to conclude, "that the lightning at Purfleet firſt ſtruck on the "point of the rod of the Conductor, and then, by a "lateral part of that ſtroke, ſtruck the cramp on the "coping-ſtone. I believe, if he had examined the "ſituation of the ſtone, and the place where the "cramp was ſtruck, he would have found, that, if "the lightning had ſtruck on the point of the Con-"ductor, that, to have produced that effect on the "ſtone, it muſt, after it had ſtruck on the point, "and paſſed down a quantity, have ſtruck from the "metal up into the air, then down again on the "cramp, and then again to the metal it had left; for "the ſmall dent or hollow made by the lightning was "on the upper ſurface of the ſtone, and yet the metal-"lic communication to the earth continued from "the theory, and ſoon ſat about performing ſeveral experiments, in which the natural accident was imitated by art *. Mr. Wilson's great apparatus was fixed in the Pantheon, Oxford-ſtreet. It conſiſted principally of the following parts:—A cylinder, 16 inches in diameter, and 155 feet long, covered with tin-foil, formed the prime Conductor, which was charged by a good electrical machine of the common ſort. This vaſt Conductor was ſuſpended by various ſilk ſtrings, at a convenient diſtance

"the point under the ſtone which was ſtruck. It "appears more probable to me, from the trifling "damage it did, that the charged cloud had paſſed "over the pointed Conductor, and had been ex"hauſted of a great part of its Electricity in paſſing; "and that, after it had paſſed, it was attracted down "lower by a ridge of hills that was beyond, and that "the cloud being out of the influence of the point to "prevent its ſtriking, the end of the cloud might "ſtrike at an angle in the cramp, and ſo to the metal"lic part of the Conductor, which was only about "7 inches below. I ſhall conclude with obſerving, "that Mr. Henly and myſelf had the pointed rod "of the Conductor at Purfleet taken down to ex"amine the point; but we found no appearance on it "that ſhewed that it had been ſtruck."

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* The account of thoſe experiments is inſerted in the 68th vol. of the Phil. Tranſ.

from the floor and walls. To this Conductor there was added a wire 4800 feet long, which was alſo ſupported by ſilk ſtrings, and, on account of its prodigious length, was bent in a great many places, going backwards and forwards in various directions. Sometimes this wire was ſeparated from the great cylinder; but, for the generality of experiments, they were made to communicate together, ſo as to form one extenſive Conductor.—By means of a proper frame and machinery, a wooden model of the above-mentioned houſe, that was ſtruck by lightning, was made to paſs with different required degrees of velocity under and acroſs one end of the great cylinder. This model was furniſhed with a Conductor at top, which was ſometimes terminated in a point, and at other times ended in a ball, but which was made to communicate with the earth by as good a metallic communication as can be deſired by the moſt ſcrupulous experimentator. Whilſt the model of the houſe was kept at a proper diſtance from the great cylinder, and after a known number of turns of the wheel, the model being let go, paſſed under the end of the cylinder with any required velocity, and at the moment that paſſed immediately under the charged cylinder, it received the ſtroke from it upon its Conductor, &c. Now, the principal experiments which Mr. WILSON made with this apparatus, are briefly expreſſed in the following articles:

1. When the model was furniſhed with a ſharp Conductor, on being made to paſs under the charged cylinder, it drew off a good deal of the electric fluid from it in a ſilent manner, and that abſorption, as it may be ſaid, began long before the model came quite under the cylinder, as was ſhewn by the appearance of light, &c. The charge which afterwards remained in the cylinder was inconſiderable: all which ſhews the tendency that a point has to draw the electric fluid ſilently, and from a diſtance.

2. If, inſtead of a point, the model was furniſhed with a knobbed Conductor of the ſame length with the pointed one, the quantity of electric fluid drawn off in re-

peating the above experiment was not ſo conſiderable as before, and it was almoſt nothing, if the knobbed Conductor was much ſhorter than the pointed one, as could have been expected.

3. When the model with the ſharp Conductor was made to paſs under the cylinder fully charged, the pointed Conductor was generally ſtruck with a full and ſtrong exploſion; whereas, if the Conductor was terminated in a ball (though of an equal length with the pointed Conductor, and conſequently equally diſtant from the cylinder when the model was juſt under it) it was not ſtruck, the cylinder remaining charged, &c.

4. "The weight which moved the mo-
"del in the preceding experiment, was
"gradually reduced till it was nearly ba-
"lanced by the friction; and when the
"motion was rendered ſo ſlow as ſeven
"feet ſeven inches in ſeven ſeconds, it
"was very little accelerated; and in
"this ſtate the great cylinder being charg-
"ed, the model was ſuffered to paſs; and,
"though

" though the velocity was leſs than three
" quarters of a mile in an hour, the point
" was ſtruck."

The intelligent reader may remark, that by the above-mentioned obſervations, the already-known properties of points were clearly ſhewn; that the very reaſons before advanced by various philoſophers, for preferring pointed Conductors of lightning to ſuch as are blunted, were confirmed; but, however, that one remarkable obſervation, which could have been hardly believed before, was eſtabliſhed, *viz.* that a point in thoſe circumſtances could receive ſo full a ſtroke, as we have mentioned above. Indeed this is a very good obſervation of Mr. WILSON, and a moſt plauſible argument in favour of his opinion relating to the conſtruction of the Conductors of lightning. Hence he expatiates upon the danger of thoſe houſes, which are furniſhed with elevated and pointed Conductors; and abſolutely recommends knobbed conductors, which are either even with, or rather a little ſhorter than the top of a building; ſince, ſays he, the pointed Conductors invite the lightning. It is almoſt ſuperfluous to remark, that it is for that very property, that elevated and pointed Conductors are preferable to knobbed ones, *viz.* becauſe they attract the matter of lightning from a greater diſtance: hence they may defend a greater extent of building; hence, by drawing a conſiderable quantity of electric fluid from the clouds, when at a diſtance, ſo as to leſſen their charge, they may thus actually avoid a full exploſion; the intention of putting a Conductor to a houſe, being to defend the houſe from the bad effects of lightning, and not the Conductor itſelf from attracting the matter of or being ſtruck by the lightning.—When the Conductor of a houſe is ſtruck, the only damage it can receive in that caſe, it ſeems, can only ariſe from a lateral exploſion between the Conductor and other pieces of metal, or other very good Conductors, which are contained in the houſe, and are not properly connected with the Conductor. For this reaſon, it is proper to connect with the Conductor, by a metallic communication, all the pieces of metal, and indeed other good Conductors, as a ciſtern of water, &c. that are in a houſe, eſpecially thoſe which are near the outſide, and the top of it. This, however, is almoſt impoſſible to be done perfectly; but then thoſe lateral effects are not of ſo very dangerous a nature, excepting indeed when the building contains ſubſtances of a very combuſtible quality, as gun-powder, &c. in which caſe, the moſt ſcrupulous attention is hardly ſufficient to prevent any bad accident. Notwithſtanding the obviouſneſs of the above-mentioned remarks, Mr. WILSON's experiments determined ſeveral perſons in favour of the knobbed Conductors: hence Mr. NAIRNE undertook to oppoſe Mr. WILSON's theory with a clear and convincing ſet of experiments. The prime Conductor uſed by Mr. NAIRNE was one foot in diameter, and ſix feet long, conſequently by far ſmaller than that uſed by Mr. WILSON. The other apparatus was different, and the electrical machine was much more powerful than that uſed by Mr. WILSON *. But with this

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* See Mr. NAIRNE's account of thoſe Experiments, &c. in the 68th vol. of the Phil. Tranſ.

this apparatus he amply ſhows the properties of points and knobs, with reſpect to Electricity; and, different from Mr. WILSON, ſhows, that in many experiments, and under various circumſtances, a knob is ſtruck in preference to a point. This diverſity of appearances, and reſults of experiments, in caſes ſeemingly alike, will at firſt ſight be thought a contradiction; but, when duly conſidered, the different phenomena may be all reconciled to a few very ſimple and natural propoſitions: *viz.* 1. A point draws the electric fluid from an electrified body, from a much greater diſtance than a blunt-terminated body; but the quantity muſt be limited, and ſubject to be altered by many cauſes; ſuch are, the degree of condenſation of the electric fluid upon the electrified body; the time given to the point; the acuteneſs of the ſaid point; its free or encumbered ſituation; its perfect or imperfect communication with the earth, &c. Thus, if the pointed body be not made to communicate with the earth, but the communication be interrupted by a ſhort interval, then, on preſenting a body ſufficiently charged with electric fluid, to the ſaid point, a full ſpark will go from th former to the latter, becauſe the point, on account of the interruption of communication, cannot diſcharge to the earth, or other fit body, the electric fluid by little and little, conſequently cannot receive it ſilently from the electrified body to which it is expoſed, but can attract only that quantity which can leap between the interruption, and which paſſes in the form of a ſpark. Thus alſo, if the point is ſuddenly brought within a ſufficient diſtance of a ſtrongly-electrified body, it will receive a ſpark, becauſe a ſufficient time was not allowed it to draw off the electric fluid ſilently, as would happen if the point was gradually brought near. After the ſame manner, the ingenious reader may imagine a great multiplicity of caſes, in which a point may be ſtruck or not ſtruck by an electrified body; hence is derived the apparent contradiction between the experiments of Mr. HENLY, Mr. WILSON, Mr. NAIRNE, and various others: but it always remains true, that a pointed or ſharp-edged body draws the electric fluid from a greater diſtance than thoſe bodies which are blunt or more obtuſe, all the other circumſtances being the ſame in both caſes.

Lord MAHON, in his above-mentioned work, ſhews a property of electric atmoſpheres, which he calls the *returning ſtroke*, and which he is of opinion that can occaſion great damage in ſome caſes. This is that quantity of electric fluid, which, by the vicinity of a cloud highly electrified, is driven away from certain bodies, and which ſuddenly returns to thoſe bodies when the cloud happens to diſcharge its Electricity by a ſtroke of lightning to any other body; for then the atmoſphere which kept off the electric fluid of the bodies that were within its action, ceaſes at once. Our noble author ſhews experimentally, that ſuch a returning ſtroke may occaſion great damage, even at a good diſtance from the place where the ſtroke of lightning happens, and that its effects may be very conſiderable; all which confirms the already-made obſervation, *viz.* that all the beſt and largeſt conducting bodies that are in a houſe, ſhould be connected with the Conductor of lightning. Without detaining my reader with further diſquiſitions, I ſhall only take notice of the moſt notable particulars that ſhould be kept in view, and ſhould be conſidered as the leading principles in erecting Conductors for the lightning; and ſhall then conclude with the *requiſites neceſſary* for the proper conſtruction of Conductors, which requiſites I ſhall tranſcribe exactly from Lord MAHON's work.

A pointed body attracts the matter of lightning more or leſs eaſily, according as it is more or leſs acute; according as it is leſs or more encumbered by ſurrounding bodies; or as it is more or leſs elevated, and as its communication with the earth, by means of conducting bodies, is more or leſs perfect. The clouds are bad Conductors, and in general the electric fluid is not highly concentrated on them in proportion to their extent; they are often ſeparated from each other; they may come towards a Conductor or a houſe in every direction; and move with various velocities at different times. The pointed Conductor that is erected in order to tranſmit the lightning with ſafety to the ground, can only defend a limited extent of building, the quantity of which varies according to many circumſtances. In caſes of powder-magazines, and ſuch-like very combuſtible ſubſtances, great damage may be occaſioned by a lateral exploſion or returning ſtroke, if the Conductor happened to be ſtruck; which may be only avoided by making a proper communication between all the ſubſtances of a good conducting nature that are in the building.

In conſequence of all thoſe obſervations, and various others mentioned in the courſe of this book, it ſeems proper to have in view the following inſtructions, in erecting Conductors for the lightning.

1. "That the *rods* be made of ſuch ſubſtances as are, in their nature, the beſt *Conductors* of Electricity."

2. "That the rods be *uninterrupted*, and *perfectly continuous*."

3. "That they be of a *ſufficient thickneſs*."

4. "That they be perfectly *connected* with the *common-ſtock*."

5. "That the upper extremity of the rods be as *acutely pointed* as poſſible."

6. "That it be *very finely tapered*."

7. "That it be *prominent*."

8. "That each rod be carried, in the *ſhorteſt convenient direction*, from the point at its upper end, to the *common-ſtock*."

9. "That there be neither *large* nor *prominent* bodies of metal upon the top of the building propoſed to be ſecured, but ſuch as are *connected with the Conductor* by ſome proper metallic communication."

10. "That there be a ſufficient *number* of high and pointed rods: And,

11. "That every part of the rods be very *ſubſtantially* erected."

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No III.

EXTRACT OF A LETTER FROM MR. ARDEN, LECTURER IN NATURAL PHILOSOPHY, DATED SEPTEMBER 25, 1772.

" ABOUT fourteen or fifteen years ago, in the preſence of WM. CONSTABLE, Eſq; at his ſeat at Burton Conſtable, in Holderneſs, I made the following experiments:

" I placed a large coated jar, that would hold three or four gallons, directly under the prime Conductor of a very good electrical machine. The prime Conductor was at leaſt eight or ten inches above the top of the jar, and the communication was made by a braſs wire, bent at one end over the prime Conductor, and the other end paſſed through a ſmall glaſs tube (contrived by Mr. CONSTABLE to prevent the electric matter from eaſily flying off) was ſuſpended in the middle of the jar, and had a ſmall piece of braſs chain faſtened to it, that reſted on the bottom of the jar.

"I then began to turn the wheel, and, after turning about 100 or 150 times, as low in the jar as I could ſee for the coating, I perceived a ball of fire, much reſembling a red-hot iron bullet, and full three quarters of an inch in diameter, turning round upon its axis, and aſcending up the glaſs tube that contained the braſs wire, which was the Conductor to the inſide of the jar,

"I immediately aſked Mr. CONSTABLE, if he ſaw the ball of fire? he ſaid, Certainly. I ſaid, I will turn on. He anſwered, By all means. I kept turning the wheel, and the ball of fire continued turning upon its axis, and aſcending up the glaſs tube till it got quite upon the top of the prime Conductor. There it turned upon its axis ſome little time, and then gradually deſcended, turning upon its axis as it had done in its aſcent, and ſo continued till it was ſo much below the top of the coating that we could no longer ſee it. But ſoon after this, a very great flaſh was ſeen; a large exploſion was heard, and ſtrong ſmell of ſulphur was perceived all over the room; a round aperture was cut through the ſide of the jar, as fine as if it had been cut with a diamond, rather more than three quarters of an inch in diameter, and between two and three inches below the top of the coating, and the coating was torn off all round the aperture, about three or four inches in diameter. The jar was a pretty ſtrong one, of crown glaſs.

“ I then took another jar, ſo like the firſt, that when both were whole I could not eaſily perceive any difference between them. I then attempted to charge this jar, in the ſame manner as the other, and we both obſerved it very accurately. No ball of fire was ſeen, but preſently the jar diſcharged itſelf with a great flaſh and explosion, and at about the ſame part as of the firſt jar; but inſtead of the aperture which was made in the firſt jar, there was a circle about three quarters of an inch diameter, as white as chalk, and the coating torn off round about it as before. Upon touching the white part, it dropped out, and appeared to be glaſs in a fine powder.

" We broke ſeveral other different-ſized jars that day, (which made Mr. CONSTABLE ſay we were in great luck), but without any thing elſe remarkable.

" The firſt experiment was made ſoon in the afternoon of a clear day, and the machine ſtood directly between us and a window, which was not above a yard from it. I don't hear that this ball of fire has been produced by art by any one elſe, to this day, although it is often produced by nature.

" I had the pleaſure of ſeeing Mr. CONSTABLE this day, and of reading the account of theſe experiments to him, and, to the beſt of his memory, he thought the whole was ſtrictly true.

" Mr. CONSTABLE thinks it would not be difficult to repeat the experiment, and to produce the ball of fire at any time, provided the jar is large, and not coated too near the top, and that the wire communicating from the prime Conductor to the inſide of the jar is made to paſs through a ſmall glaſs tube, (which is certainly of great advantage in making experiments of this kind) and that the machine acts very ſtrong. If not, it will be in vain to attempt it."

AFTER this letter, Dr. PRIESTLEY, out of whoſe works it has been tranſcribed, ſubjoins the following remarks * :—" The fact mentioned in the preceding letter is of a very remarkable nature, and, being perfectly well aſcertained, it is of importance that it be generally known, and kept in view. For though no perſon, that has hitherto been made acquainted with it, has been able to repeat the experiment, others may be more fortunate. Dr. FRANKLIN, and, if I miſtake not, Mr. CANTON alſo, and myſelf, were preſent when Mr. HENLY endeavoured to produce this appearance; but, though every expedient that any of us could ſuggeſt was made uſe of, we had no ſucceſs, and I have ſeveral times attempted it in vain ſince. I ſhall not, however, deſiſt from my attempts.

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* Experiments on Air, &c. vol. v.

" Mr. ARDEN's own evidence is abundantly ſufficient to authenticate the fact, and I have ſince had from Mr. CONSTABLE himſelf the ſame account of it. Could we repeat this experiment, there would not, I think, be any natural phenomenon, in which the electric fluid is concerned, that we could not imitate at pleaſure. This circumſtance alone makes it a very intereſting object of inveſtigation."

Nº IV.

N° IV.

OBSERVATIONS CONCERNING SOME PROPERTIES OF THE ELECTRIC FLUID.

AMONGST the various experiments performed by Mr. Wilson in the Pantheon, as mentioned in the preceding pages, he made ſome with a long wire, which was ſuſpended by ſilk lines, and went in various directions through that great building. This wire was 4800 feet long, and $\frac{1}{21}$ of an inch in diameter. It conſiſted of many pieces, which were connected by twiſting the ſeveral ends together. —Mr. Wilson electrified this extended wire by means of an electrical machine ſituated next to one of its extremities; and when the wire was fully charged, which happened after a few turns of the wheel, a perſon diſcharged it, by preſenting his hand to it, which was attended with a ſhort ſpark, but with a very diſagreeable ſtrong ſhock. Then Mr. Wilson took an equal length of wire, of the ſame diameter with the above-mentioned extended one, and, putting it all coiled together upon a glaſs ſtand, charged it with electric fluid, by means of the ſame machine, and when this wire was fully charged, which took place after about half a turn of the wheel, a ſpark was taken from it, but which occaſioned a ſenſation by no means comparable with that given by the extended wire, ſince this, though longer than the ſpark of the extended wire, was hardly to be felt, whereas that was remarkably ſtrong.

The explanation of thoſe effects might eaſily occur to a perſon little verſed in Electricity. The extended wire acquired a much greater quantity of Electricity than that which was coiled up, for the ſame reaſon for which an extended piece of tin-foil, twenty ſquare feet wide, and which weighs one pound, can acquire incomparably more Electricity than a ſolid ball of tin, which weighs one pound alſo; namely, becauſe the extended wire expoſes a far greater ſurface to the free air, than the wire that is coiled up; and the ſpark given by the coiled wire is longer than that given by the other, in ſo much as the electric fluid, whatever its quantity may be, can be much more condenſed on the coiled than on the extended wire; it being well known, that the length of the ſpark given by electrified Conductors is proportional to the condenſation, and not to the quantity of electric fluid.

To obſerve, that the extended wire required many turns of the wheel before it became charged, whereas the coiled wire required leſs than one turn; the obſervations made and mentioned by various writers on Electricity, relating to the capacity of Conductors under various circumſtances; Dr. FRANKLIN's experiment of the *can* and *chain*, and innumerable other experiments of the like nature, might have convinced Mr. WILSON of the truth of the above-mentioned natural and clear explanation; but, upon thoſe phenomena Mr. WILSON eſtabliſhes a principle which does not ſeem ſatisfactory. He imagined, that in ſo much the extended wire gave a much ſtronger ſhock than that which was coiled up, as the electric fluid percurring the whole length of the extended wire acquired a great degree of velocity; hence the impetus with which it ſtruck the hand or other body preſented to the charged wire, occaſioned that diſagreeable ſenſation, which ſenſation was not accompanied with the ſpark given by the coiled wire, becauſe the electric fluid could not acquire any velocity, as it did not go through a great extent of conducting ſubſtance.

This theory ſeems to be not true, for the following reaſons. Firſt, It is well known that metal, and in general any ſort of conducting ſubſtance, does in ſome meaſure reſiſt the free paſſage of the electric fluid through its ſubſtance; hence the electric fluid, in going through a long Conductor, muſt be retarded rather than accelerated. Secondly, The electric fluid being elaſtic, whenever a way is open for it to eſcape out of a Conductor, upon which it has been confined, it muſt exert its greateſt force at firſt; that is, the quantity of it, which comes out at firſt, has the greateſt velocity, becauſe it is impelled by the greateſt expanſive force; but, according as more and more of the electric fluid comes out of the Conductor, that impelling force or elaſticity leſſens; hence the laſt particles of electric fluid come out of the Conductor with leſs velocity; thus in a condenſing fountain, out of which the ſtream of water iſſues, on account of the elaſticity of the air condenſed in the cavity of the inſtrument, the ſtream at firſt comes out with greater violence, and mounts higher up, but afterwards loſes its velocity by degrees, becauſe the condenſed air becomes gradually leſs and leſs condenſed, and conſequently exerts a force continually ſmaller and ſmaller againſt the water. Laſtly, It may be obſerved in general, as it has been proved by many experiments, that if two unequal Conductors, one of which A is more extended than the other B, diſcharge equal quantities of electric fluid under the form of ſparks from like terminations, the ſpark given by A is leſs ſtrong than the ſpark given by B, and that for the above-mentioned reaſons.

Notwithſtanding the obviouſneſs of thoſe remarks, Mr. WILSON, ſince he firſt made the experiments at the Pantheon, ſeems to have become continually more and more attached to his opinion, ſo that about two years ago, he publiſhed a ſmall tract, entitled *A ſhort View of Electricity*, in which he endeavours to eſtabliſh his theory of the acceleration of the electric fluid, &c. upon mathematical principles. This ſtep determined me to take notice of it in this Appendix, in order to prevent any wrong notions in the heads of novices; for perſons who are not converſant with mathematics, will take any propoſition for true, when they are aſſured that it is mathematically ſo. Mr. WILSON's theorem conceals a fallacy, and ſhews that a perſon very well ſkilled in a ſcience, as Mr. WILSON is in Electricity, can eaſily fall into a miſtake, when he is too much attached to a favourite opinion.—Mr. WILSON's words are as follow:

"*Upon Acceleration.*

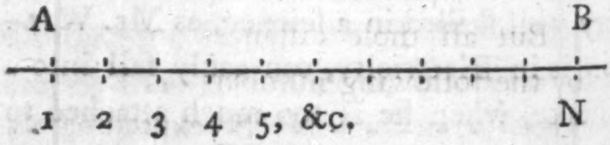
"The experiments at the *Pantheon*, "which were intended to ſhew the accele-

“ ration of the fluid, having been objected to by many, who have not ſufficiently attended to the known properties of the elaſtic fluid, it has been thought proper here to eſtabliſh this very material point upon mathematical principles, with a view to put an end to all farther diſputes on the ſubject.

“ But before this is done, it may be neceſſary to mention a material fact that was omitted in the account of thoſe experiments; which is this,

“ The ſhock received at the *middle* of the long wire, was *conſiderably* leſs than that which was received at either end.

“ THEOREM.



“ Let A B repreſent a cylinder of a given diameter, and ſuppoſe this cylinder charged with the electric fluid. I ſay, if all the particles of this fluid are moved at the ſame inſtant towards A,

" the effect produced by the ſhock of this " fluid at A will be nearly proportional " to the ſquare of A B; for the total effect at A is equal to the ſum of the effect of each particle contained in the " cylinder A B: and the effect of each " particle being proportional to its velocity, the total effect at A will be proportional to the ſum of all the velocities. " But ſince the fluid is ſuppoſed nearly " perfectly elaſtic, all the particles will " arrive at A nearly at the ſame inſtant; " then the velocity of each particle will " be proportional to the diſtance from the " place it ſets out, and the total effect at " A will be proportional to the ſum of all " thoſe diſtances.

" But all thoſe diſtances are expreſſed " by the following numbers, 1, 2, 3, 4, 5, " &c. - - - - - - - N (N expreſſing the " length A B) in an arithmetical progreſſion. Then the ſum of all the diſtances " will be expreſſed by the ſum of the " arithmetical progreſſion 1, 2, 3, 4, 5, " &c. - - - - - N, and the effect at A

" will be proportional to this ſum, that is
" to ſay, to N^2 or AB^2. Q. E. D."

Mr. WILSON's abſtract propoſition is certainly evident, *viz.* " That if all the particles of the electric fluid are moved at the ſame inſtant towards A, (by which, I ſuppoſe, he means if they arrive at A in the ſame inſtant of time) the effect produced by the ſhock of this fluid at A will be nearly proportional to the ſquare of A B." But this propoſition cannot be poſſibly applied to the matter of fact, or actual experiment, ſince the condition upon which the propoſition depends cannot be verified; *viz.* we do not know whether or no the particles of the electric fluid that are in the long wire, do all arrive at one end of it preciſely at the ſame time. Beſides, we may ſafely ſay, that from the conſiderations mentioned in the preceding pages, and from the analogy of other natural phenomena, it appears that they do not, and cannot arrive to the extremity of the wire preciſely at the ſame time. Between the particles of electric fluid which arrive firſt at one extremity of the wire, and thoſe which arrive laſt at the ſame extremity, there is an interval, a difference of time. Mr. WILSON ſays, "all the particles will arrive at A, *nearly* at the ſame inſtant." Now, even that *nearly* implies a length of time, which, however imperceptible it may be to our ſenſes, is yet ſufficient for the natural operation. For inſtance, ſuppoſe that the extended and electrified wire is a mile long, and alſo ſuppoſe that a quantity of electric fluid employs one hundredth part of a ſecond of time to percur that length of wire, and that without acceleration, or even with a little retardation, which is by no means an exaggerated ſuppoſition. Now, if a way be opened to the electric fluid in the wire, *viz.* the hand, &c. be preſented to one extremity of it, the neareſt particles of the electric fluid will come out firſt, and the remoteſt laſt; yet that difference, agreeably to the ſuppoſition, does not exceed one hundredth part of a ſecond, which is abſolutely unperceivable by our ſenſes; ſo that the appearance is exactly the ſame as if all the particles of the electric fluid came out of the extremity of the wire preciſely at the ſame inſtant of time. I think, therefore, that what Mr. WILSON imagines to have eſtabliſhed upon mathematical principles, is far from being mathematically demonſtrable. Without dwelling any longer upon Mr WILSON's propoſition, and the corollaries which he deduces from it, I ſhall only take notice of a remarkable experiment he made at the Pantheon, with the already-mentioned apparatus; which, however, he attributes to the accumulated velocity, which the electric fluid acquired in percurring the ſubſtance of a very long Conductor.

Mr. WILSON fired gun-powder by means of the ſtream of electric fluid, but without ſpark or ſhock. The method is as follows, in his own words: "Upon a ſtaff "of baked wood a ſtem of braſs was fixed, "which terminated in an iron point at the "top. This point was put into the end "of a ſmall tube of Indian paper, made "ſomewhat in the form of a cartridge, "about two-tenths of an inch in diameter. "When this cartridge was filled with "common gun-powder, (unbruiſed) the "wire of communication with the well

" was then faſtened to the bottom of the " braſs ſtem. Being ſo circumſtanced, and " whilſt the charge in the great cylinder " and wire was continually kept up by " the motion of the wheel, the top of the " cartridge was brought ſo near to the " drums as frequently to touch the metal. " In this ſituation, a ſmall, faint, luminous " ſtream was obſerved between the " top of the cartridge and the metal " drum.

" Sometimes this ſtream would ſet fire " to the gun-powder at the inſtant of the " application; at others, it would require " half a minute, or more, before it took " effect. But this difference in time " might probably ariſe from ſome difference " in the circumſtances; for any the " leaſt moiſture, &c."

It ſeems that in this experiment the gunpowder was fired by the heat occaſioned by the denſe ſtream iſſuing out of the vaſt Conductor, which diſcharged a prodigious quantity of electric fluid in that concentrated manner. This experiment was afterwards imitated by Mr. NAIRNE, with the Leyden phial. When a large electric jar was charged, Mr. NAIRNE preſented the cartridge of gun-powder, ſimilar to that uſed by Mr. WILSON, to the knob of the jar, and the powder was fired without any exploſion of the jar. In this experiment, the wire upon which the cartridge was fixed, did not communicate with the outſide of the jar by a good conducting communication, but both the outſide of the jar, and the ſaid wire, did communicate with the ground; ſo that it may be ſaid, that the circuit between the two ſides of the jar was imperfect; hence the diſcharge was not made by a full exploſion.

I ſhall laſtly conclude this work, with juſt mentioning ſome very remarkable improvements lately made by Mr. VOLTA, an account of which he has ſent to the Royal Society. — This great philoſopher has advanced the ſcience of Electricity a good ſtep beyond what was known a year or two ago, ſince he has found the means of diſcovering exceedingly ſmall degrees of Electricity, and ſuch as are not perceivable by any other method already known. Mr. Volta obſerves, that when a metal plate, belonging to his electrophorus, is charged with Electricity, if it be laid flat upon an imperfect Conductor, as for inſtance, upon a very dry piece of wood, a dry marble ſlab, an oil-cloth, &c. it will preſerve the Electricity for an incomparably longer time than if it were kept inſulated in the air; and farther, that it will preſerve the Electricity, even if it be touched ſeveral times with the finger, or other inſulated Conductor, whilſt it ſtands upon the imperfect Conductor; ſo that if afterwards it be taken up by its glaſs handle, it will ſtill give a ſenſible ſpark.—If the ſaid metal plate, or other conducting body, inſtead of being laid flat, be made to touch the imperfectly-conducting plane edgeways, the Electricity is immediately loſt.—If the imperfectly-conducting plane be inſulated, the electrified metal plate that is laid upon it will not preſerve the Electricity nearly ſo long as when the ſaid plane is not inſulated.

A metal plate, by being laid flat upon an imperfect Conductor, is not only enabled to retain its Electricity much longer than when inſulated in the moſt perfect manner, but it does alſo acquire the property of receiving Electricity from ſuch bodies, which either for their imperfect electric nature, or for the ſmallneſs of their ſize, could not communicate to it any ſenſible degree of electricity. Thus, if whilſt the unelectrified plate is laid in full and flat contact with an imperfect, and not-inſulated conducting plane, it be ſtroked a number of times with a piece of paper, or linen, not quite damp, or with leather, and even with the naked and dry hand, or with the knob of a phial juſt diſcharged by a compleat communication between its ſides, it will from thence acquire a ſmall indeed, but ſenſible degree of Electricity, ſo that if afterwards it be taken up by its glaſs handle, and be preſented to an electrometer, it will ſenſibly affect it, and ſometimes it will even give a ſmall ſpark if the finger is preſented to it.

Mr. VOLTA juſtly attributes the cauſe of thoſe phenomena to the metallic plate's increaſed capacity for holding electric fluid, whilſt it ſtands in flat contact with an imperfect Conductor, and to its capacity being diminiſhed when it is ſeparated from that contact.

My judicious reader muſt eaſily perceive that this principle is applicable to an innumerable number of purpoſes; as, to the examination of the weakeſt atmoſpherical Electricity, to the excitation of imperfect electrics, &c.; it is therefore very proper for thoſe who are anxious to diſtinguiſh themſelves in Electricity, to purſue the hint, and enlarge this principle, which ſeems to open the eaſieſt road to numerous and important diſcoveries.

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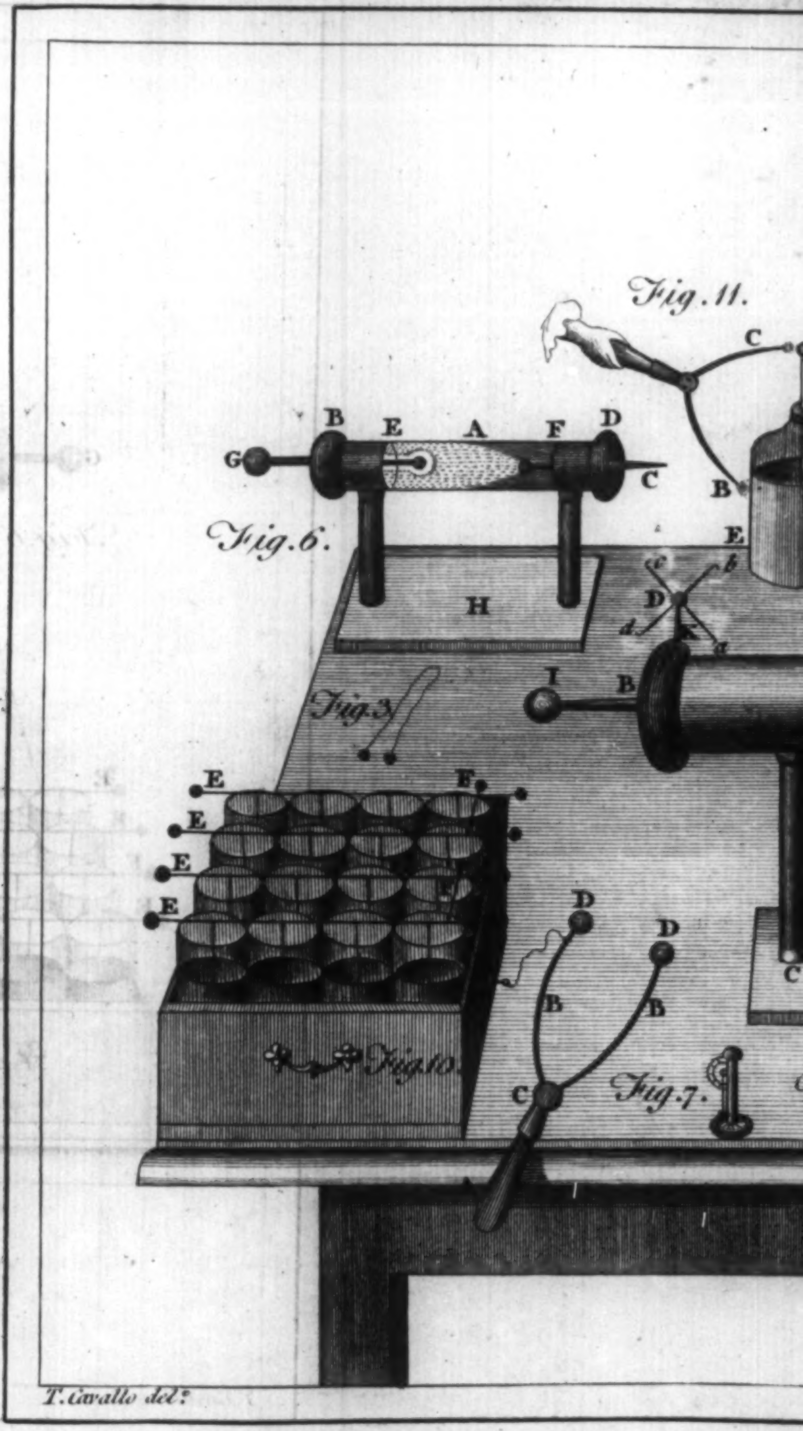

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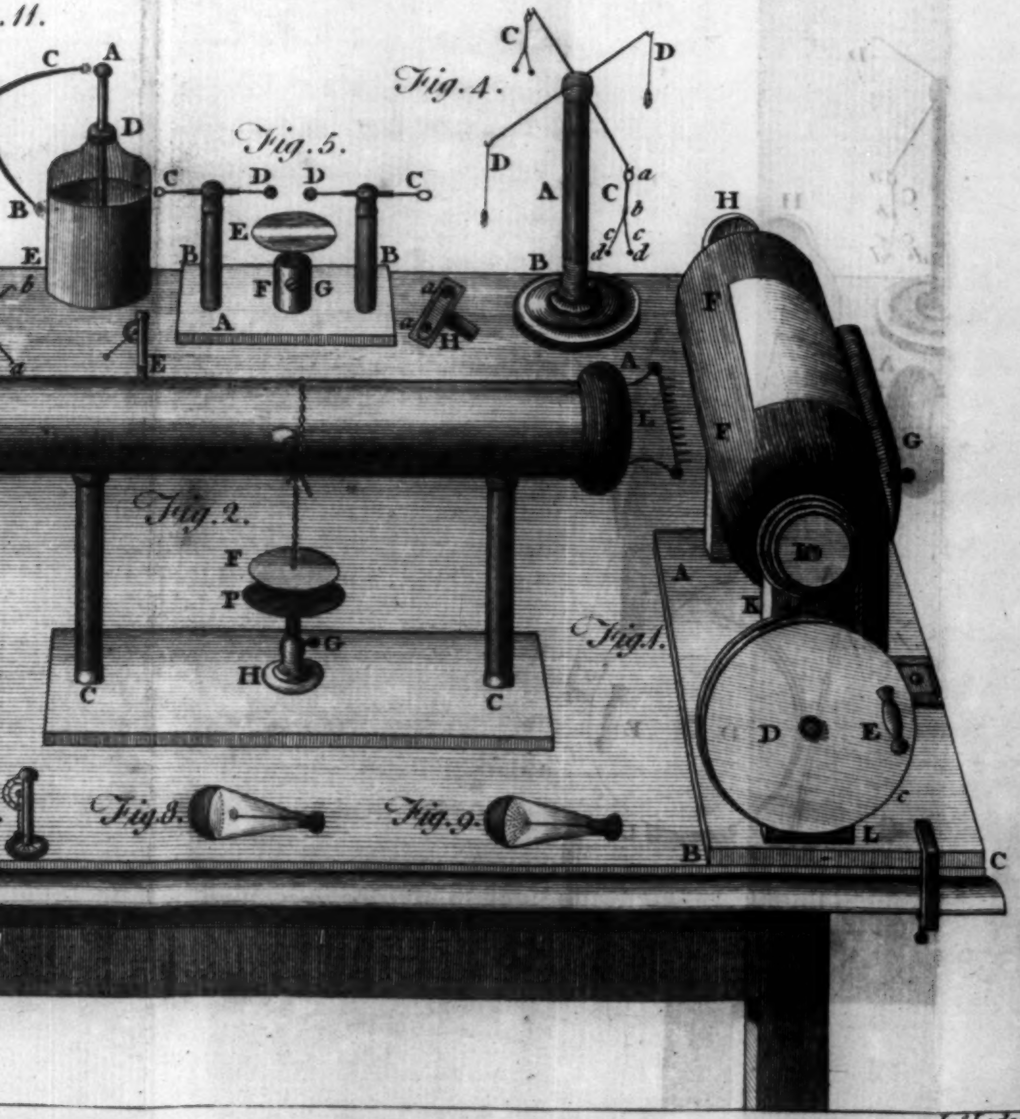


Jn.º Lodge Sculp.

Fig. 4.

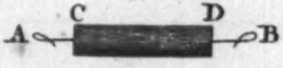


Fig. 5.

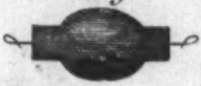


Fig. 6.

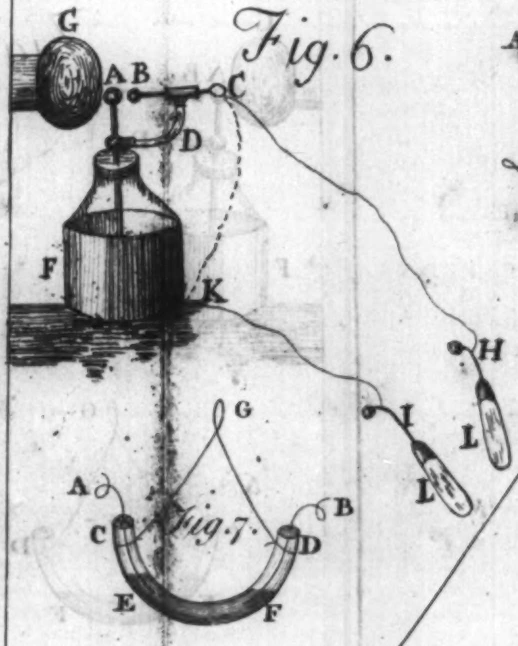
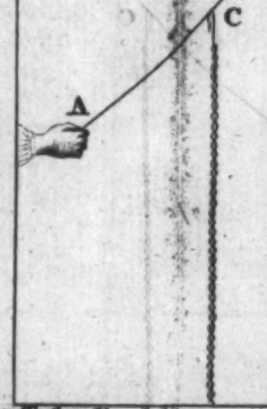


Fig. 7.

Fig. 8.



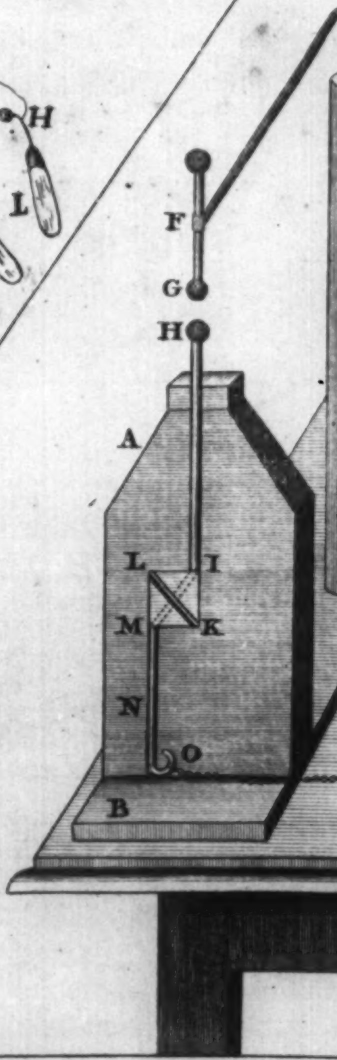


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PLATE II.

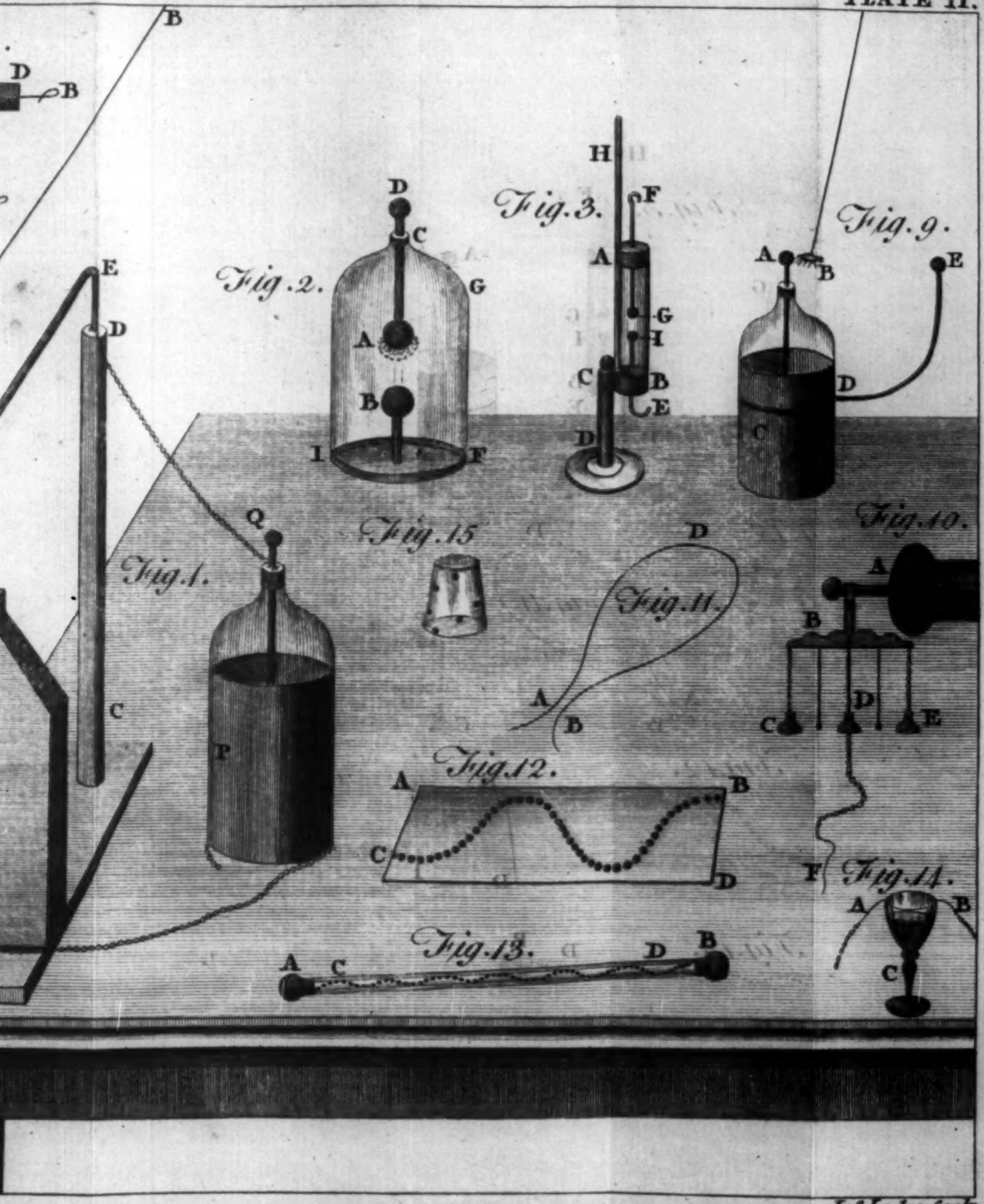

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Fig.

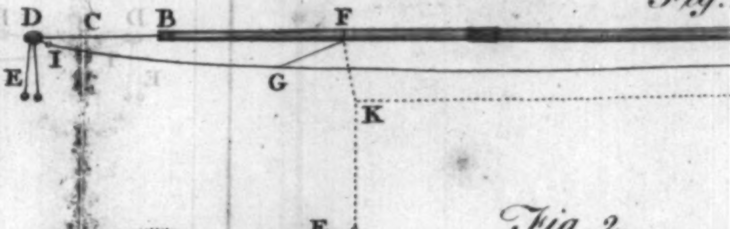


Fig. 2.

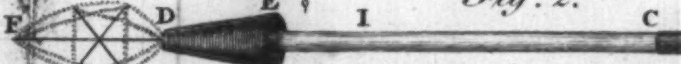


Fig. 3.

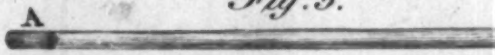
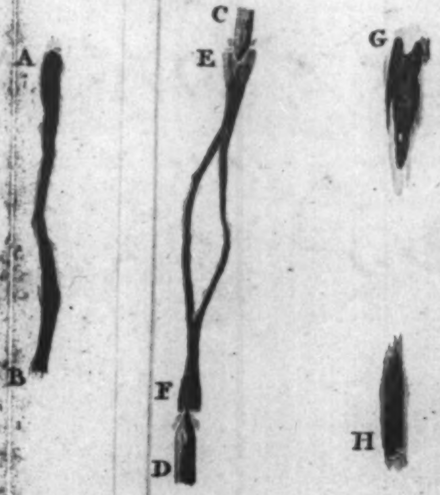


Fig. 7.



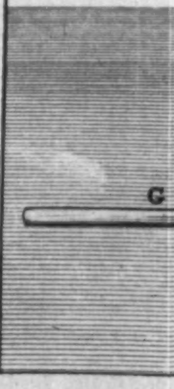


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PLATE III.

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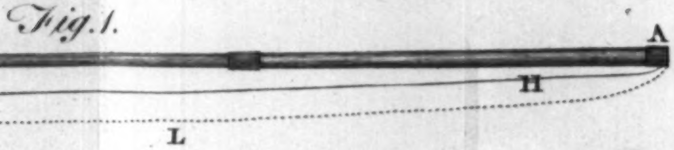

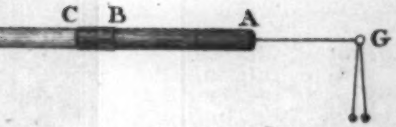

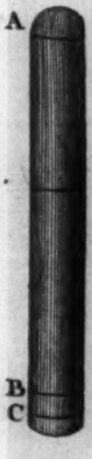

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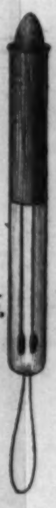

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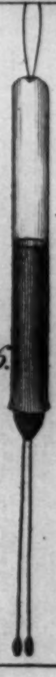

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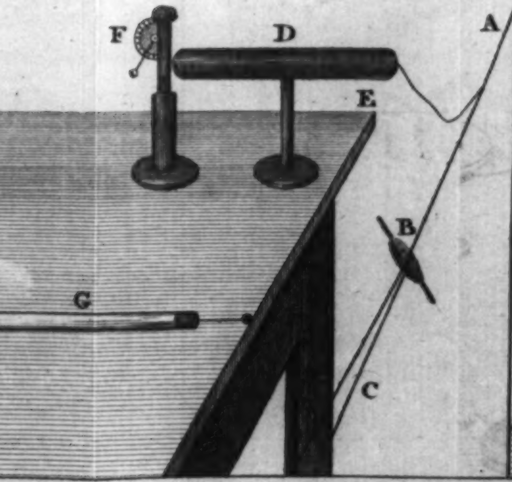

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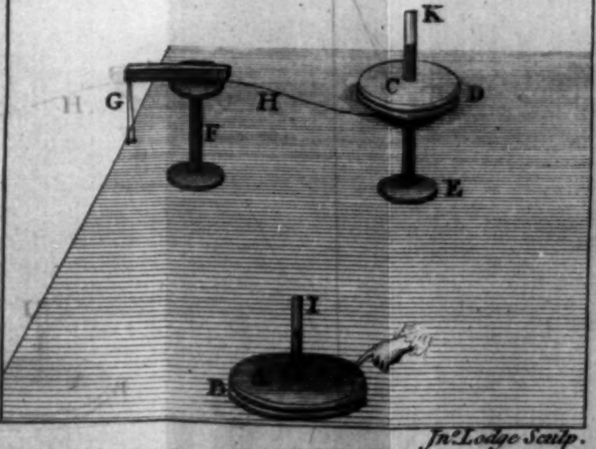

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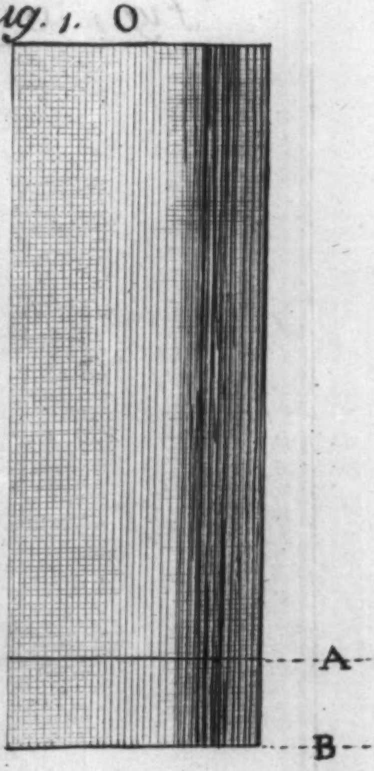

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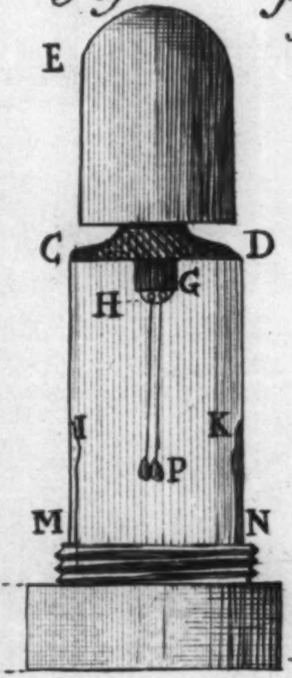

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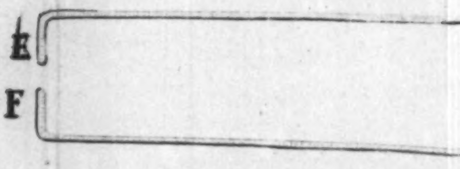

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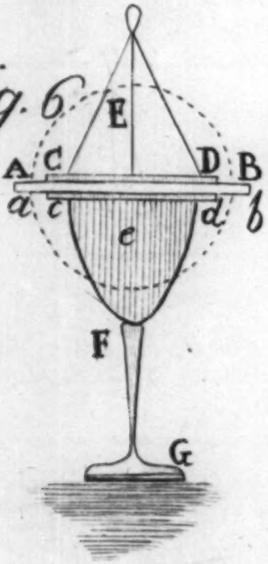

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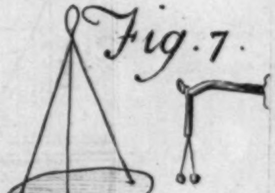

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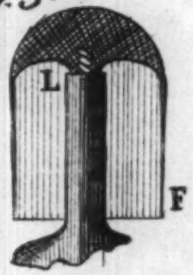

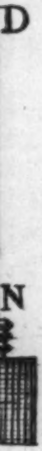

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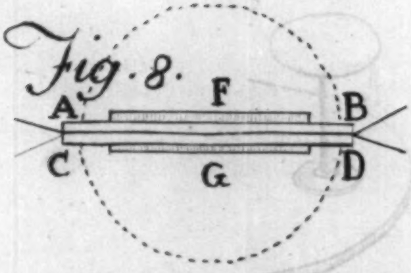

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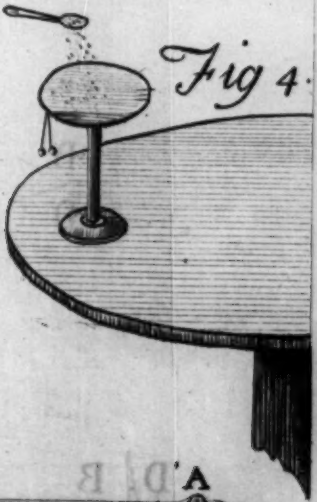

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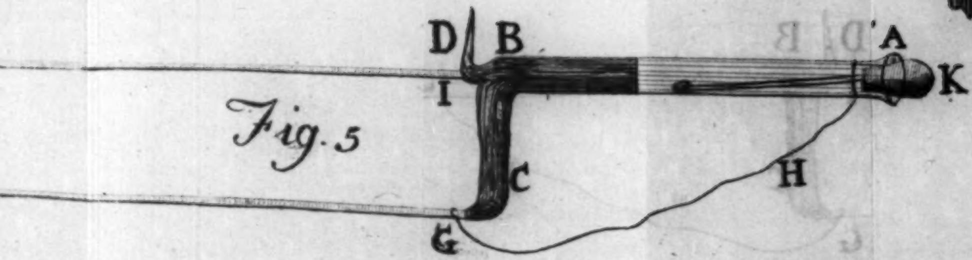

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